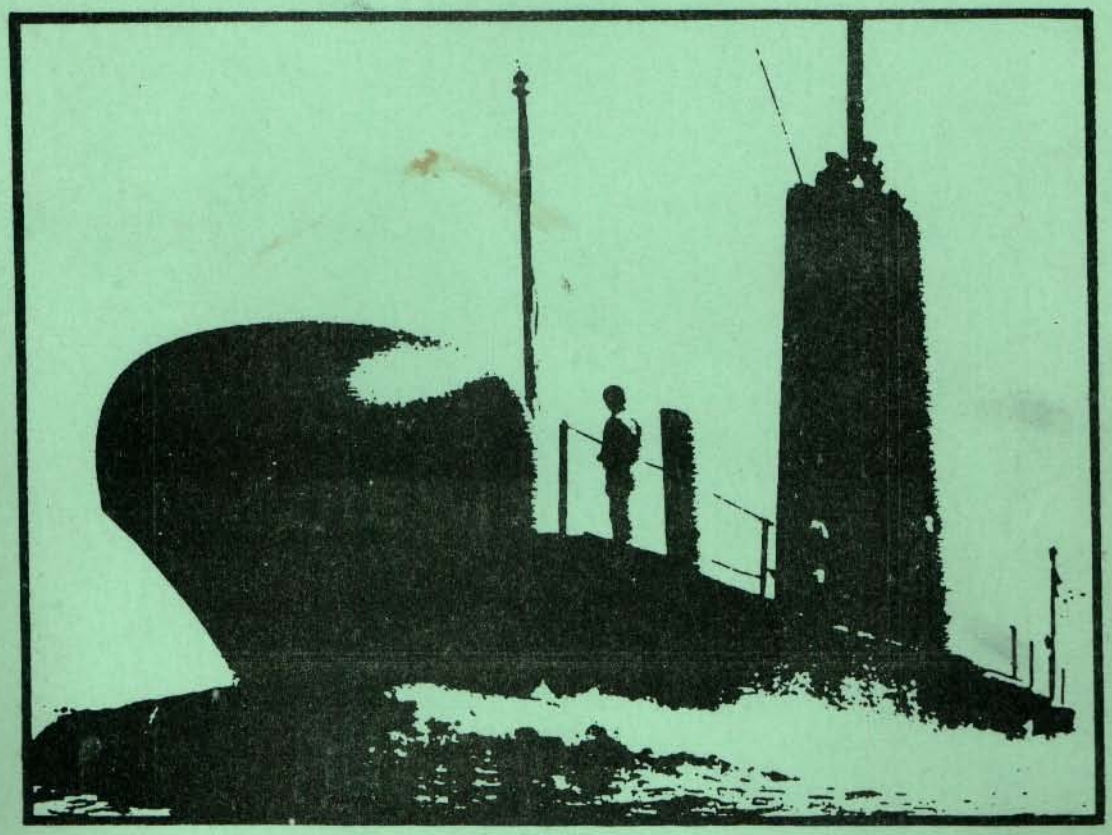


# "O" CLASS SUBMARINE
# STAGE THREE
# MISCELLANEOUS SONAR
# AND NAVAIDS
# COURSE HANDBOOK

# UNDERWATER TELEPHONE TYPE 183

## Purpose:

Type 183 is an Emergency Underwater Telephone installed in Submarines to provide a means of communication with rescue ships when a Submarine is in distress.

## Brief Description:

A battery operated tranciever with a dual purpose Microphone/Headphone, permanently connected to a fixed transducer in the casing of the Submarine. The set consists of two boxes, the Tranciever and the battery box, which is always kept locked. Also near the set is a battery for use when the set is being tested. The set is able to transmit continuously for 22 ½ hours and recieve for 12 ½ days continuously.

## Tranciever:

The tranciever is made up of three sub-units:

(A) Modulator.
(B) Transmitter.
(C) Reciever.

The sub-units are potted in a synthetic resin and enclosed in a metal screening box. Also mounted on the chassis are the O/P transistors, O/P transformer, S/R switch, volume control and the Crystal which is part of the Oscillator.

## Circuit Description:

In the same block as the modulator is a crystal controlled oscillator and AGC amplifier for the reciever. The Oscillator supplies the carrier for Modulation and Demodulation. A SSB suppressed carrier system is used.
The S/R swicth controls the operation of the reciever by switching the microphone, transducer and the 12V supply to the reciever of transmitter. The 12V supply to the Modulator Block and the -6V bias supply are not switched by the S/R switch.

## Circuit Description: ( TX )

With the S/R switch to send, audio signals from the Microphone are connected by the bandpass filter 1L1, 1C1, 1C2 and 1R1. This restricts the input to the transmitter to frequencies between 800 Hz and 3 KHz. The signal is then amplified and then fed by an emitter follower to the Ring Modulator and mixed with the Carrier.
The Carrier of 8.0875 KHz is generated by the Oscillator. The level of the Oscillator is controlled by the diode 2MR1, which regulates the bias of 2VT1 via the Emitter Follower 2VT2.
The output is then connected to a Filter circuit where frequencies higher than 8.8 KHz are passed. Negative feedback ensures low input resistance to this stage. Signal is further amplified in a Driver Stage and fed to a Class B push-pull amplifier output stage. The neon lamp is connected across the Output Transformer and lights when the Output exceeds ¼ W.

## Circuit Description: ( RX )

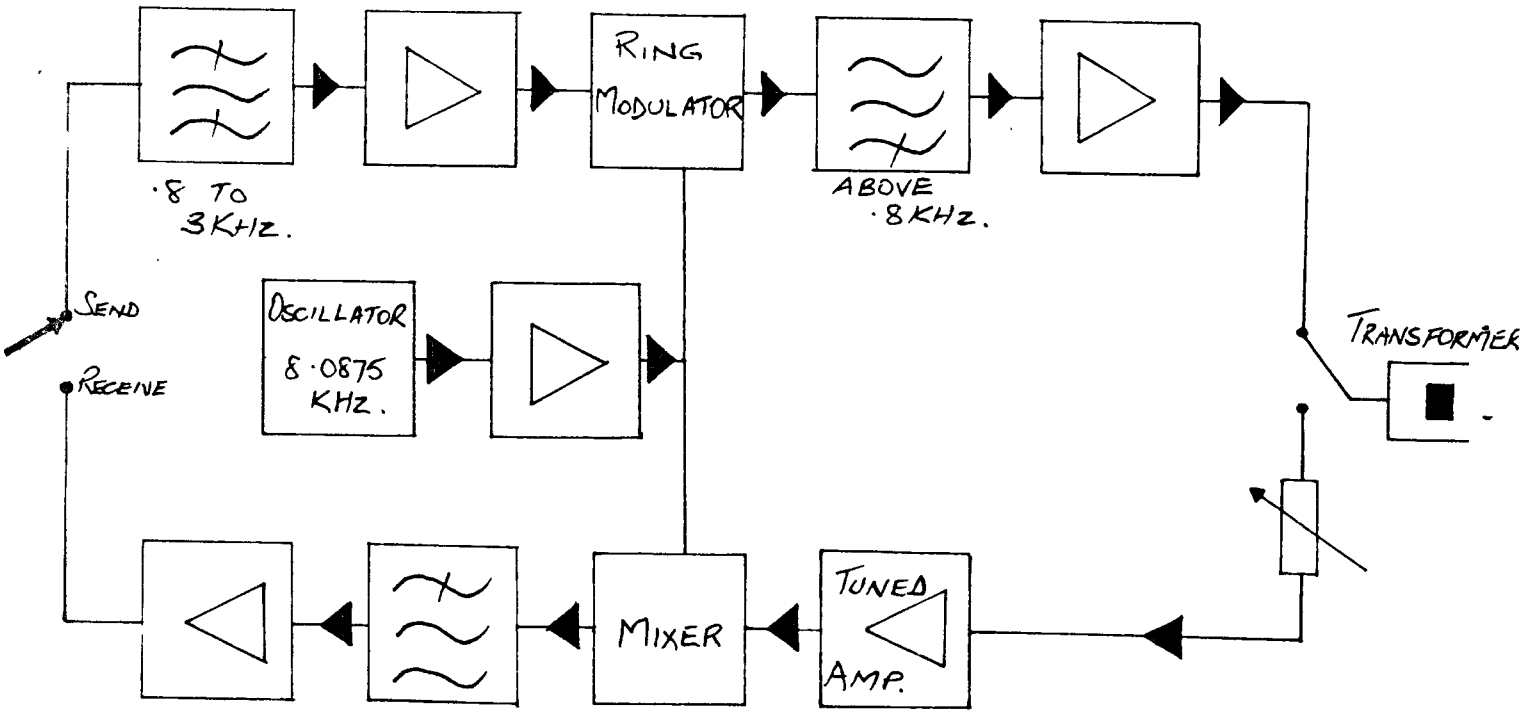
With the S/R switch to recieve, the transducer is connected to the reciever Input Transformer. The gain of the two stages is controlled by the AGC amplifier. The Modulator now functions as a Demodulator, and the signal is mixed with the Carrier. The output of the Demodulator is fed via the Volume Control to a low pass filter. The Output of this filter is now audio and is fed to the reciever Output Transistor, supplying the Microphone which is now used as a Headphone. The reciever Output is 1 mW into a 300 Ohm Microphone/Earpiece. To accomodate this range of signals strengths, the Agc circuits are incorporated to reduce the need for critical setting of the Volume control.

Circuit Description ( RX ) Cont.
A portion of the amplified signal is tapped of the input to the Modulator and fed to the AGC detector and Amplifier which is in the Modulator Block. To maintain level control between words when recieving speech, the AGC circuit is arranged to Charge quickly and Discharge slowly.

Power Supply:
This is provided by a dry battery. The battery contains a high capacity 12 V section for main HT and a -6V section for bias supply.

Transducer: (120° conical beam over a maximum range of 1000 Yards.)
The Transducer connected to the Sonar 18 3 is the same as the Transducer connected to the Sonar Type 185. Therefore the Capacitance and Insulation requirements are the same.
The Transducer cable comes out of the Tranciever Box and then goes to a Cable Changing Box mounted near by. It is in the Cable Changing Box that the Polythene Cable is connected to the Tranciever Box. The Polythene Cable then goes out of the Submarine through a Hull Gland. The cable then runs along a cable tray until it reaches the Transducer.

Monitor/Test Plugs:
A Monitor plug is connected to the DEAD side of the battery to provide a means for connection of the TEST BATTERIES. The TEST Socket is used to test the FITTED battery under a NO LOAD condition.




BLOCK DIAGRAM 183 UWT.

Attenuator:
The attenuator consists of a switch potentiometer having four reductions of 10 dB's and is operated by the Transmitter Power Switch on the control panel.

Driver and Power Amplifiers:
V4 is a pentode amplifier whos output feeds V5 and V6, a long tail pair, providing a push-pull output to the power amplifiers V7 and V8. The output of the PA's is fed to the appropriate transducers via the Transducer Selector Switch.

## RECEPTION

Preamplifier and Filter:
The recieved signal from the transducer is fed to the transformer, coupled to V10. A pentode amplifier who's output is fed to the bandpass filter FL2. In thr filter unit, there is a 50 dB attenuator which is controlled by the operation of the NEAR/DISTANT switch and is used to attenuate strong signals in the near position. The output of the filter is fed to V11.

Amplification and Demodulation Stages:
V11 and V12 are RC coupled pentode amplifiers. The output of V12 id fed to the demodulator M2, which is also fed from V9 oscillator.

Output Stage:
The output from M2 is fed to a low pass filter circuit and then amplified by V13, the output of which is taken to a loudspeaker and two phones sockets.

## GENERAL

All the electronic components are located in one small cabinet, with the power unit housed in the base and the remaining components on the inside of the front cover. For ease of replacement, a number of components are made up of sub units: These are:

(1) Preamplifier.
(2) Modulator.
(3) Filter.
(4) Driver.
(5) Carrier Oscillator.
(6) Reciever.
(7) Modulator.
(8) Filter.

Transmitter Protection Switch:
Is a microswitch operated by the movement of the Transducer Selector Switch, and is open whilst the switch is being changed from one position to another. HT2 is interupted by the switch and is removed from the reciever, the TX preamplifier and thr driver, and the screens of the power amplifier valves. In this way, the transmitter is protected when the load is open circuited while switching from one transducer to another.

## SONAR TYPE 185 UNDERWATER TELEPHONE

Provides either voise or SST communication between surface ships or two submarines.
Communications may be:
(a) Over an arc of 120° upwards or on either beam.
(b) Omnidirectional ( A combination of fixed transducers ).
These arcs of coverage may be selected by the operation of the Transducer Selector Switch, the positions of which are:
(a) Omni.
(b) Starboard.
(c) Upper. ( One to casing, one to Fin.)
(d) Port.

### POWER SUPPLIES:

The power unit is supplied with 115 V 50/60 Hz and provides the HT, bias, heater and relay supplies for the equipment.
HT 1 : 650 V for the Transmitter Power Amplifiers.
HT 2 : 200 V for the reciever and transmitter and the screens of the Power Amplifier.

### HEATERS:

6.4 V Three similar windings providing heater outputs of 4-5 amps. These three windings when connected in series are used in conjunction with a rectifier to provide approx 19.5 V bias to the Power Amplifier valves V7 and V8.

### RELAY:

30 V approximately to operate the S/R relay RLY4

### BOOKS OF REFERENCE:

(1) Handbook for U/W TELEPHONE TYPE 185. BR 219.
(2) Establishment list A/S 259.
(3) Instructions for installation A/S 7076/R3.

### WARNING

When carring out tests on HT1, great care must be taken. Always ensure that C 43 and C 44 are discharged after switching off.

### SUMMARY OF OPERATION:

### TRANSMISSION

#### Preamplifier/Oscillator:

With the VOICE/SST switch to VOICE, V1,V2 and V3 act as amplifiers. With the switch to SST, V1 and V2 act as a 1 KHz oscillator and V3 remains an amplifier.

#### Carrier Oscillator and Modulator:

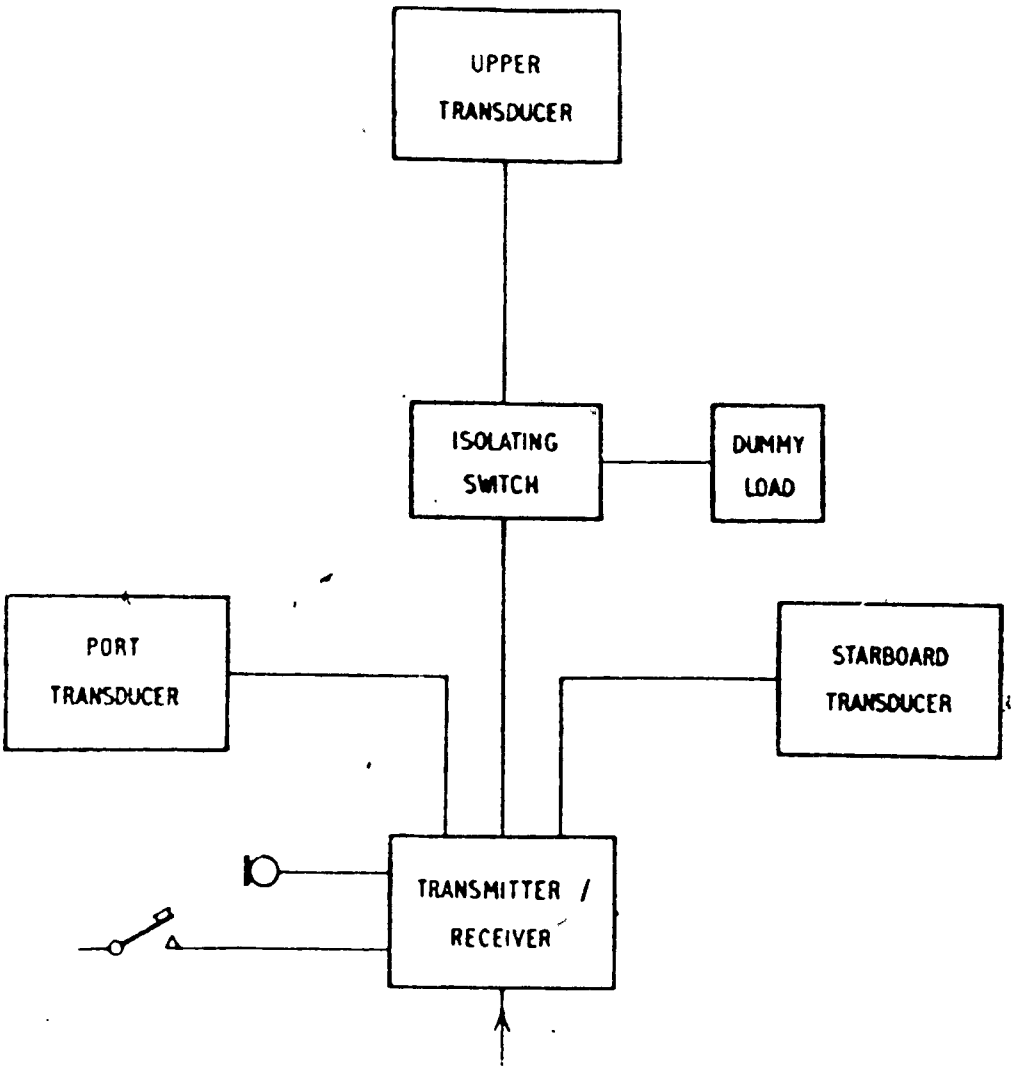
V9 is the carrier frequency oscillator which is crystal controlled.(8.0875 KHz) The output of V9 is fed to the modulator, the outputs of which are fed to the filter FL1, which removes the lower sideband.

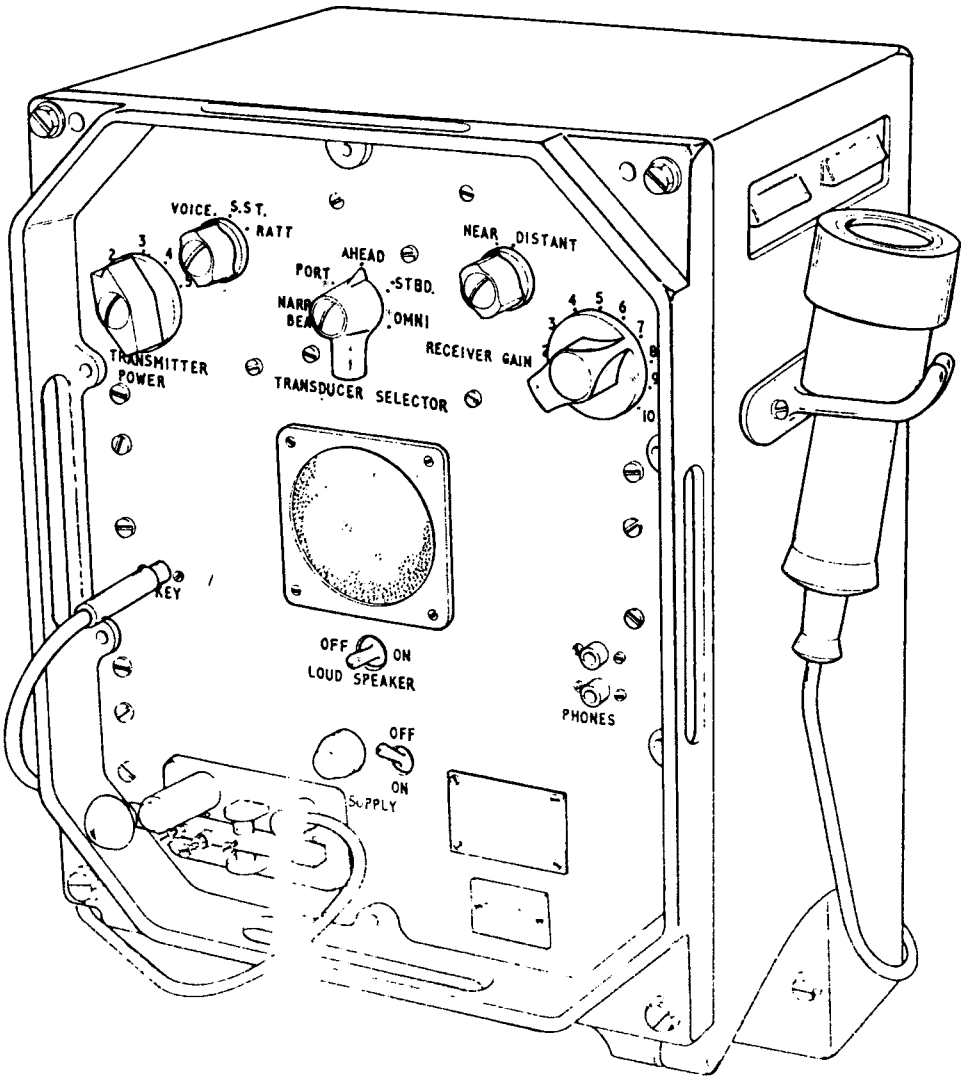
Keying Circuit:

With the VOICE/SST switch in the SST position and the Morse Key in the normal position, the output of V 3 is short circuited and the oscillations generated by V1 and V2 do not cause any output from the Modulator.
Immediately the key is pressed, the back contact is opened and these oscillations can modulate the carrier and signals are fed to the Power Amplifiers via FL1 and the driver.
The front contact of the Morse key causes RLA/4 to operate.
If this relay were allowed to release immediately the key was released the operator would here background noise in the spaces and confusion would result.
To avoid this, R2 3 and the combination of C12, C1 3 and C14 have been added.
There effect is twofold. First, owing to R2 3 the relay current does not decay to zero, but to some figure slightly less than the release current of the relay and second, the time constant of the delay is set to approximately 2.3 seconds.
With the switch to VOICE, the relay is operated by the microphone ' PRESS TO SPEAK ' switch and is deenergised on release.

Transducer:

The Transducersare made up of Longitudinal sandwich type elements of Barium Titanate, resonant at approximately 10 KHz. Transducer capacitive readings should always be within 300 pF of each other when measured at the console.
Spare Transducers are normally supplied with a lenght of cable. In the case of Polythene cables, it is not intended that the whole of the cable run be replaced. A joint should be made as close as possible to the old transducer. It is essential that the lenght of the cable run be maintianed in order that the capacitance figures are within the prescribed limits. Capacitance between the connections from each transducer, taken at the console connection box, should be at least 6000 pF and the insulation between them at least 2.5 Megohms.

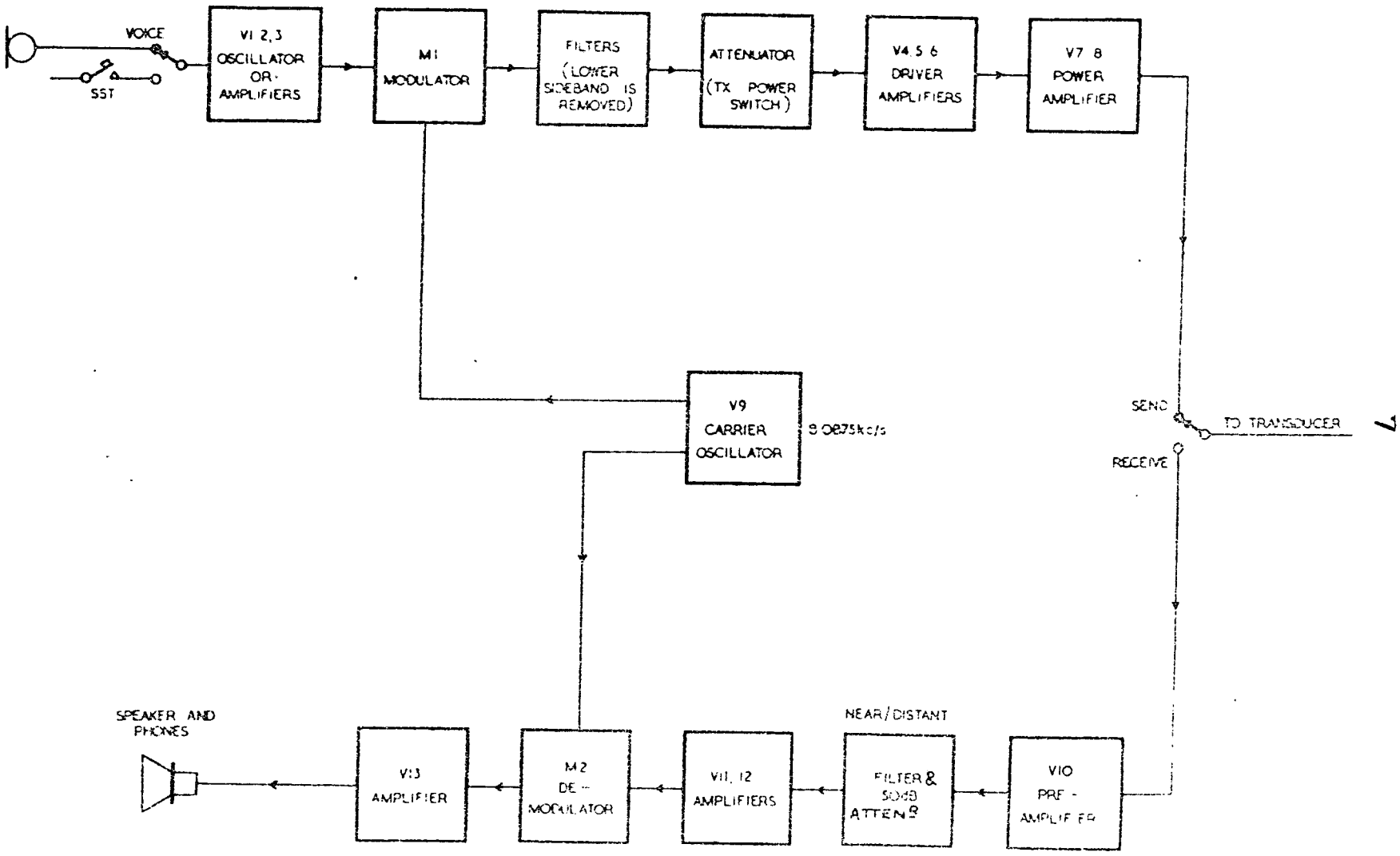




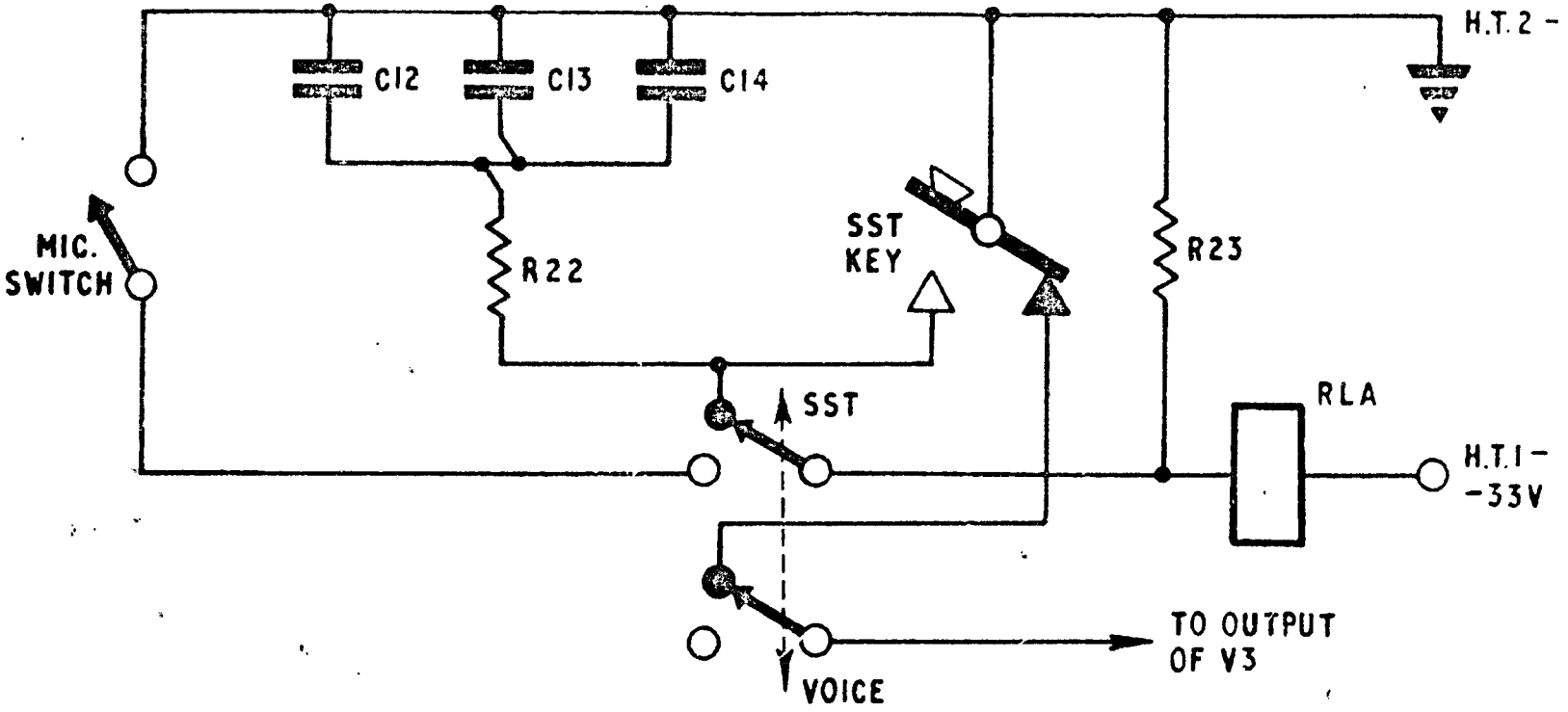

# RECEIVER/TRANSMITTER

FIG. 1.1
Amendment 14

# TYPE 185 — TX/RX BLOCK DIAGRAM



# TYPE 185 - KEYING CIRCUIT




FUNCTIONS OF RLA

| DE-ENERGISED | CONTACT | ENERGISED |
|---|---|---|
| TXDR TO RX | 1 | TXDR TO TX |
| H.T. TO RX | 2 | H.T. TO P.A. SCREENS, TX PRE-AMP DRIVERS |
| SPARE | 3. | SPARE |

# A/S TYPE 189.

(CAVITATION MONITOR)

(PORTABLE MACHINERY NOISE MONITOR)

# A/S TYPE 189.

PURPOSE:

Type 189 is installed in a submarine as a cavitation indicator. The portable version is carried on submarines as a machinery monitor.

FUNCTION:

To provide aural detection of the onset of propellor cavitation in submarines. A portable version may be used to monitor both aurally and by meter, machinery vibration and noise producing sources in submarines and surface vessels. The portable version can also be used to detect worn bearings and noisy gears.

CAPABILITIES AND LIMITATIONS:

Type 189 allows the onset of cavitation to be determined to within 5rpm, and allows comparative measurement of propellor noise over the range of levels normally encountered. Correctly used, it can give comparative measurements, reproducing over a period to within about ±3db of the vibration levels of machinery such as gear boxes.

CAVITATION INDICATOR:

Two accelerometers mounted to the internal frames of the pressure hull, or a hydrophone mounted externally to the pressure hull, feed propellor noise to an amplifier in the control room. The noise is audible by headset and its level is given on a meter.

MAJOR UNITS:

1. Amplifier.
2. Accelerometers.
3. Hydrophones. (in lieu of accelerometers.)
4. Junction boxes. (two in number.)

PORTABLE MACHINERY NOISE MONITOR:

A portable vibration pickup is attached to the machine to be monitored. The signal is monitored by headset and meter by means of an amplifier. (As for cavitation indicator.)

MAJOR UNITS:

1. Amplifier.
2. Vibrator.
3. Portable stowage brackets.

POWER REQUIREMENTS:

Powered from an internally stowed 6.5V mercury battery. Normal life of the battery is 200 hours.

FREQUENCY OF OPERATION:

400Hz to 3KHz with a reduced response below 400Hz.

TECHNICAL DESCRIPTION:

CAVITATION MONITOR:

Comprises two accelerometers(or hydrophones) and an amplifier. Propellor noises are picked up by the accelerators and may be heard in the headphones when plugged into the amplifier. A meter on the amplifier gives an indication of the overall noise level. Since the first onset of cavitation is more readily detected as a change in the character of the noise rather than increase in level, the headphones are used to find the critical speed of the propellors at which cavitation commences. The meter is used only to assist in maintaining quiet running once the critical propellor speed has been found.

ACCELEROMETERS:

The accelerometers are small piezo-electric devices which are bolted to the frames of the pressure hull and respond to sympathetic vibrations caused by the propellors. The accelerometers are so called because, within the frequency range for which they are designed, the O/P signal has RMS amplitude proportional to the mean acceleration of the vibrating surface to which they are attached, and is of the same frequency as the vibration. Since the base plate of each accelerometer is bolted to the pressure hull, which has a large mass and large area, the O/P signal will depend mainly on vibration of the pressure hull. Airborn sound will have little effect unless it can cause the hull to vibrate in sympathy.

AMPLIFIER:

Uses seven transistors and is powered by a 6.5V(nominal) Mallory type battery. The battery is contained within the amplifier and may be withdrawn by unscrewing a cap on the front panel. A built in test facility allows the meter of the amplifier to be used to check the battery voltage.

CABLING:

The accelerometers are each fitted with fifteen feet of coaxial cable. These cables are run in clips to a junction box. From the junction box, the connections are carried by twin cored screened cables, the screen being common to both circuits. This cable terminates in a second junction box in the control room, from which coaxial cables connect to the I/P sockets of the amplifier.

FREQUENCY RESPONSE:

The important components of machinery and cavitation noise lie betwwen a few Hz and 3KHz, with the lower frequency components tending to be of greater amplitude than the higher frequency ones. Thus the system requires a response which is approximately equal for all the frequencies from 400Hz to 3KHz, but decreased for frequencies below 400Hz. The accelerometers have a frequency response which is level within ±2db from zero to 3KHz, but have a resonant frequency at about 5KHz, giving a 40db increase in sensitivity at that frequency. The amplifier is therefore equipped with a low pas filter which rejects all frequencies above 3KHz.

FREQUENCY RESPONSE:

..... The accelerometers have a source impedance which is equivalent to a series capacitance of 4000pF when the circuit is loaded by the I/P impedance of the amplifier. Losses across this capacitance cause a decrease in response to frequencies below 400Hz due to coupling losses and much reduced above 3KHz by the low pass filter.

PORTABLE MACHINERY NOISE MONITORS:

Requires no permanent cable runs and comprises a vibration pick up, an amplifier and a headset, all of which are readily portable. In use, the vibration pick up is attached by means of its magnet to the machineto be monitored. Readings of vibrations are taken on the meter of the amplifier, and the characteristics of the vibration are checked aurally by use of the headset. Provided the vibration pick up is attached in exactly the same spot and the speed of the machine remains constant, meter readings are reproducable to within ±3db or less. The portable machinery noise monitor uses the same type of amplifier as the cavitation indicator.
The vibration pick up is similar to the accelerometers of the cavitation indicator, but is equipped with a cylindrical magnet instead of a mounting stud. Frequency response and other characteristics of the two equipments are therefore similar.

VARIANTS:

Two types of amplifier are available. AP191451 for bulkhead mounting or portable use, and AP192229 for panel mounting. The two types are electrically similar, except that the panel mounting type has provision for only one I/P(from a hydrophone), whereas the bulkhead type provides for two I/P's(PORT and STARBOARD) from two accelerometers.

MAINTENANCE:

Service is limited to the checking and replacement of the batteries. The two amplifiers supplied are normally interchangeable, so allowing the amplifier of the portable machinery noise indicator to be used as as a ready use spare for the cavitation indicator. As transistors are used in this set, care must be taken when using test instruments that the transistors are not burnt out.

NOTE:

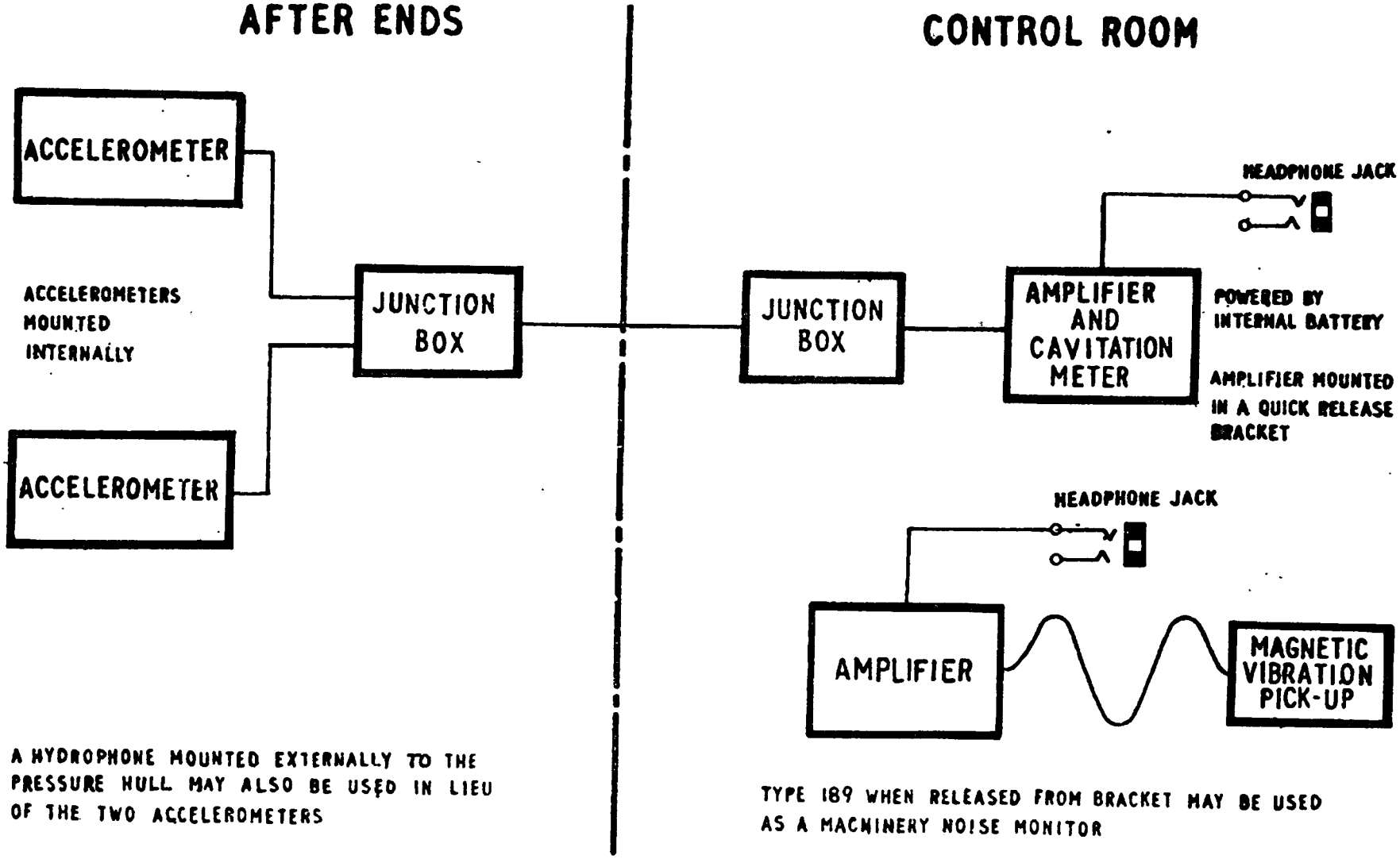
The readings obtained from the type 189 are to some extent unique to the vessel. A cross reference to absolute levels may be obtained during routine noise ranging.

REFERENCES:

1. BR 2225 Handbook.
2. A/S 269 "E" Lists-
3. A/S 7079 Installation Specifications.

TR. 796
D.P. 65/2837

# CAVITATION INDICATOR TYPE 189


AFTER ENDS
CONTROL ROOM
ACCELEROMETER
ACCELEROMETERS MOUNTED INTERNALLY
ACCELEROMETER
JUNCTION BOX
JUNCTION BOX
HEADPHONE JACK
AMPLIFIER AND CAVITATION METER
POWERED BY INTERNAL BATTERY
AMPLIFIER MOUNTED IN A QUICK RELEASE BRACKET
HEADPHONE JACK
AMPLIFIER
MAGNETIC VIBRATION PICK-UP
A HYDROPHONE MOUNTED EXTERNALLY TO THE PRESSURE HULL MAY ALSO BE USED IN LIEU OF THE TWO ACCELEROMETERS
TYPE 189 WHEN RELEASED FROM BRACKET MAY BE USED AS A MACHINERY NOISE MONITOR

# QUICK REFERENCE DATA FOR 2004

## POWER REQUIREMENTS:

Operable over a range of 103 V to 138 V 400 Hz Single Phase. (Nominal 115V) Input power requirements are 55 W single Phase power.

## TEMPERATURE RANGE:

The Transducer operates continually in Sea Water at any Temperature between -2.2°C to 35.5°C. The Recorder unit operates continually over a Temperature Range 0°C to 50°C.

## OUTPUT DISPLAY:

Recorder Sound Velocity information is displayed as rotation of a drum. Depth information is displayed by position of a stylus which writes on the Velocity Drum.

## DEPTH CALIBRATION:

0 to 1500 Feet in two overlapping ranges.
0 to 800 Feet and 700 to 1500 Feet.

## SOUND VELOCITY RANGE:

4600 to 5100 Feet per second in 5 Feet per second increments.

# SONAR TYPE 2004 (AN/BQG-1A)

This is an American sonar and is called Depth-Sound speed measuring set. It's function is to plot a graph of the Speed of Sound in water against Depth. This information is used to :

(A) Give accurate ranging on active Sonars.
(B) Plot the paths of sound rays, either by Hand or on the SFCS.

It is a completely Transistorized equipment and consists of:

(A) Two Sound Heads (Transducer Assemblies), one fitted in the top of the FIN, the other in the FOR'D end of the KEEL.
(B) One Depth Element, fitted in the control room vicinity.
(C) One Recorder fitted in the Control Room.

GENERAL DESCRIPTION:

The speed and path of Sound waves in Sea water are affected by SALINITY, TEMPERATURE and PRESSURE. Previous instuments measured these individual factors and computed the answer. Type 2004 transmits a pulse over a fixed distance and measures the time taken, thus producing the Speed of Sound directly.
A Chart is normally only produced when the Submarine is Descending or Ascending, and the leading sound Head should always be selected i.e. The UPPER Sound Head when ascending and the LOWER Sound Head when descending.
The Sound Heads and Depth Element are sealed units and should not be opened by ship's staff without special permission.

SOUND HEAD:

A Free running Crystal Oscillator produces a 64.8 KHz output to a Clipper/Differentiator. The clipper converts the Sine Wave to a Square wave, which is then Differentiated to produce Positive and Negative going 'spikes'. The Positive spikes are blocked by diodes. The Negative spikes are fed to a Frequency Divider, or circuit which produces one output pulse for every Two input Pulses. This is done to produce trigger wave forms with very rapid rise times.

The 32.4 KHz output (this is a PRF) is applied to the output amplifier and Acoustic Transmitter. The pulse length is approximately 1u Second, with a peak amplitude of 6V (approximately) with respect to ground. The Transmitter converts the signal into a sound wave with a carrier frequency of about 3 MHz.
Each pulse is also passed to a bistable multivibrator which assumes a conducting or 'ON' state. The Acoustic pulse is reflected twice and picked up by the Acoustic Reciever which converts it into an electrical signal. This low level signal is passed to a high gain, untuned Amplifier (Q101), Emitter Follower (Q102) and a thresholding circuit (Q103). The latter is normally biased beyond cutoff and prevents random signals (WATER NOISES) from operating succesive circuits.

The output of the threshold circuit is passed to a trigger generator (Q104 and Q105). These two form a SCHMITT Trigger ( a Monostable Multivibrator ). This produces an output waveform with a rise time of less than 1uS. The output is Differentiated, and the Negative going Pulse causes the Bistable to cease conducting, or assume the 'OFF' state. This completes one cycle of the Transmit and Recieve sequence, the length of time taken being decided by the water around the Sound Head, and measured by the length of time the Bistable Multivibrator was switched 'ON'.

The Characteristics of the (varying) Square Wave output of the bistable are thus related to Speed of Sound. This waveform is passed to a clamping circuit and is then Integrated (by C230 and R230 and cable Capacitance ) to give a DC voltage, the level of which varies as a function of the Speed of Sound in water. The Integration circuit is in the Recorder.

A Calibration switch is provided at the recorder, and is marked 'PRESS TO SET 4800 Ft/Sec'. It causes a fixed output from the frequency divider to be passed directly to the Bistable Multivibrator. The Recorder should then run to a figure close to 4800 Ft/Sec. (The exact figure is obtained from the TEST DATA SHEETS for the particular Sound Head ).

Sound Heads should be handled with great care to avoid damaging or offsetting the Transducers. The cables ( four in number ) enter the Sound Head and the Pressure Hull by Polythene Moulded Glands. Replacement of a Sound Head therefore necessitates cutting and joining of these four cables. Cable length should be maintained ( 125 Feet ).

Both Sound Heads are mounted in ducted cavities which ensure a free flow of water with a minimum of cavitation and turbulence.

DEPTH:
The Depth Element is a variable Reluctance device. It is excited by a 7.5 V 400 Hz supply from the Recorder. Sea water pressure is supplied by a Depth Gauge connection and any alteration is detected by a Diaphragm, which unbalances the Magnetic circuit. This produces an error signal which feeds the Stylus Servo (in the Recorder), which runs to nullify the error and causes the Stylus to indicate the correct depth.

RECORDER:
The recorder is a two channel Servo mechanism. It recieves signals from the Sound Head and Depth element to drive the DRUM and STYLUS respectively. The Drum carries a renewable peripheral chart which is capable of displaying Sound Speeds between 4600 and 5100 Ft/Sec in steps of 5 Ft/Sec.

Depth is displayed in one of two ranges, 0 to 800 Feet and 700 to 1500 Feet, selected by a two position switch. A second two position switch selects the required Sound Head. The positions of the two switches are permutated to illuminate any one of four indicator lamps.

REFERENCES:

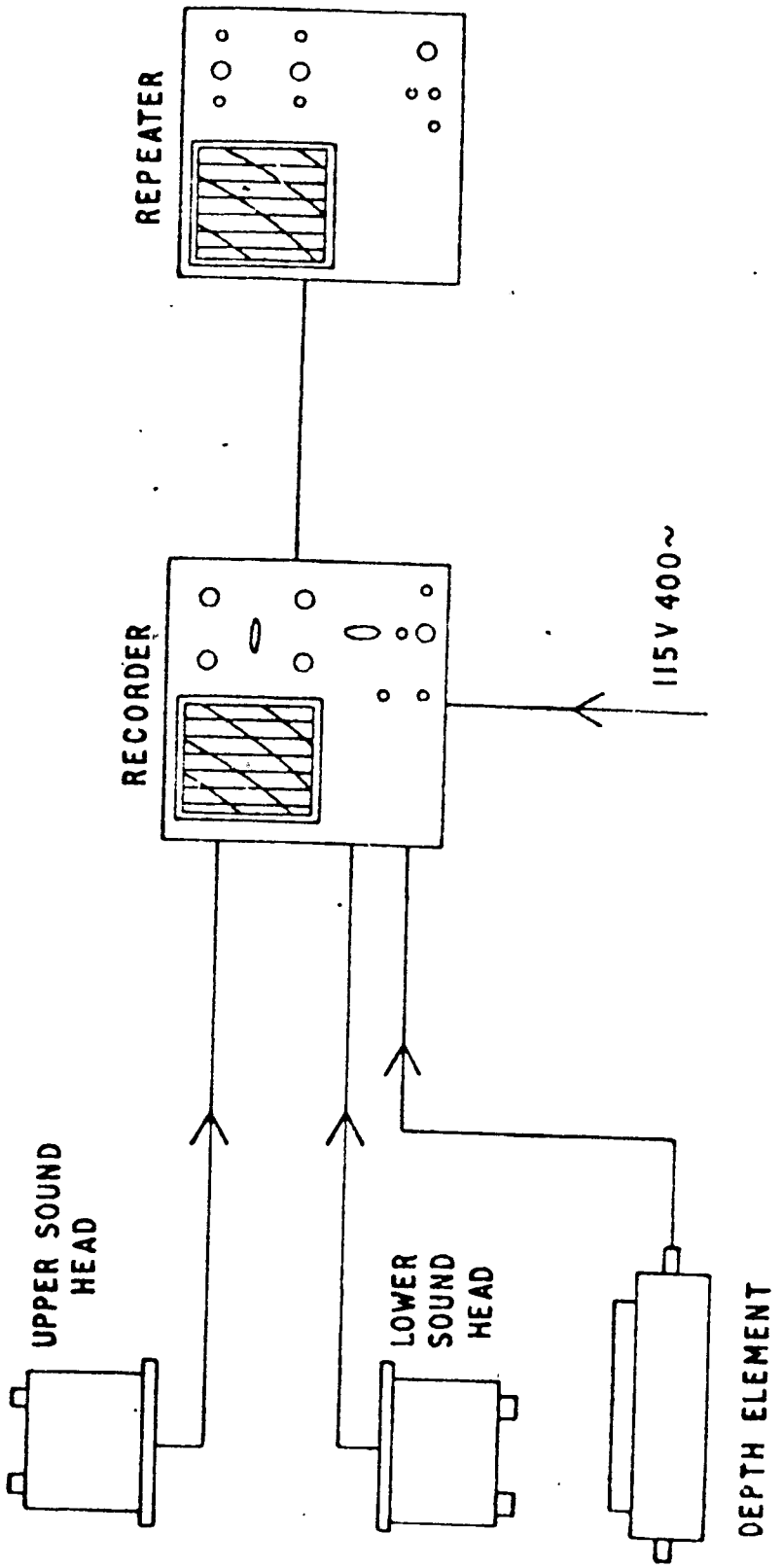
(A) Handbook - NAVSHIPS 0967-932-0010.
(B) Installation Specification - A/S 7918.
(C) Sound Head test data sheets.

CALIBRATION:
The full Calibration procedure is contained in NAVSHIPS 0967-932-0010, pages 2-10 to 2-12, paragraph 2-8a and 2-8b.
The two servos are AC. The DC level represents the sound of speed is therefore used to control the operation of a modulator, which produces a 400 Hz signal, the level of which follows the DC level. This varying 400 Hz controls the Drum Servo.

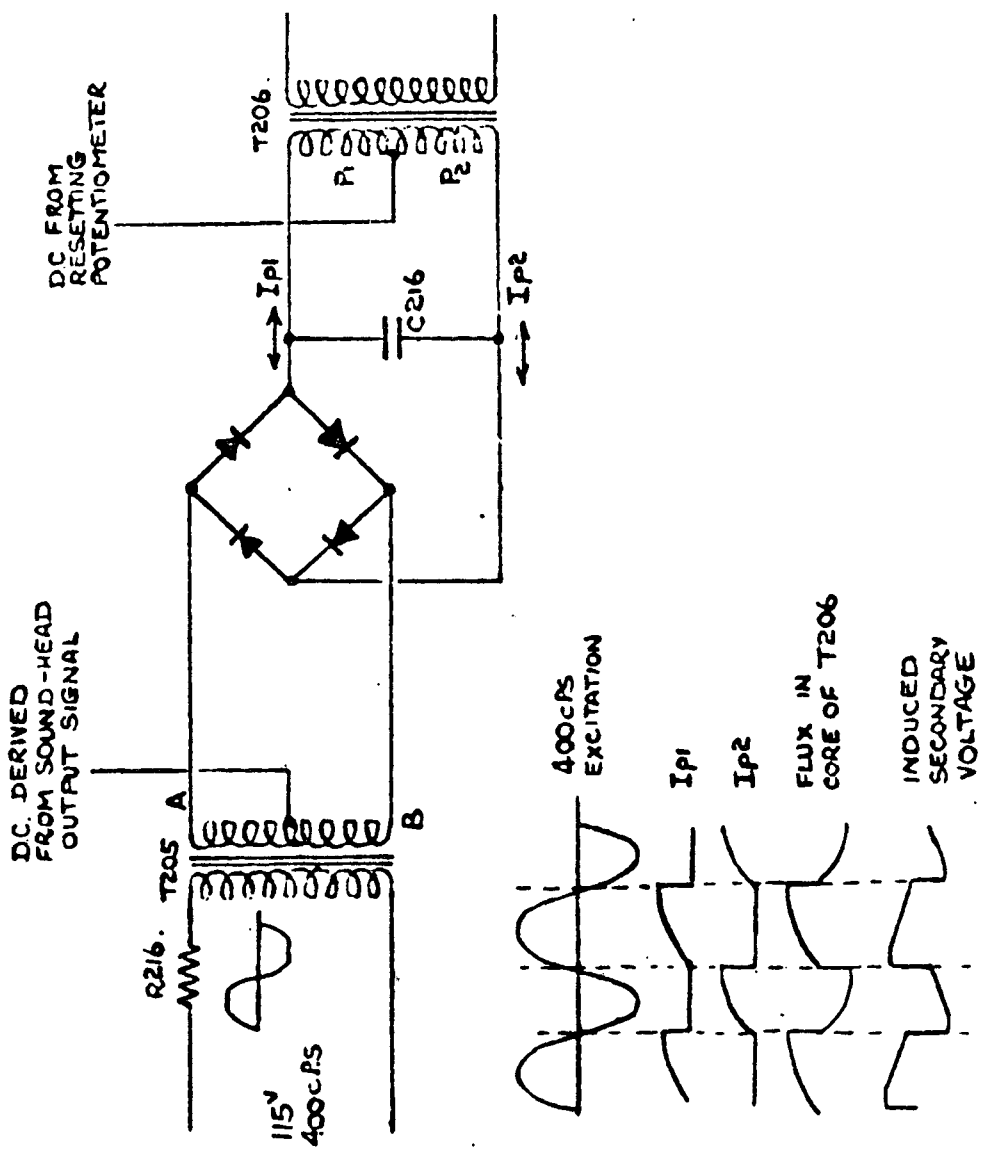
TYPE 2004 MODULATOR OPERATION:
The primary of Transformer T205 is supplied with a reference supply of 400 Hz. This is used to 'switch' the diodes in the Bridge Circuit.
The DC potential derived from the Sound Head signal is applied to the centre tap of T205 secondary, and a DC potential from a resetting potentiometer is applied to the centre tap of T206 primary.
Consider an instant when the reference supply causes point A to be positive with respect to point B. This will cause the appropriate pair of diodes to conduct. If a difference of potential exists between the two centre taps, a current (DC) will flow through both diodes (Ip1) and P1 half of T206 primary.
For the next half cycle of the reference supply, point B is positive with respect to point A. The other pair of diodes will now conduct, giving current (IP2) through P2 half of T206 primary. The 2 currents IP1 and IP2 are following in opposite directions in T206 primary causing an alternating voltage at 400 Hz in the secondary. The amplitude of this induced secondary voltageis proportional to the potential difference between the two centre taps, and it is used to drive the Drum servo and resetting potentiometer.

FIG 1

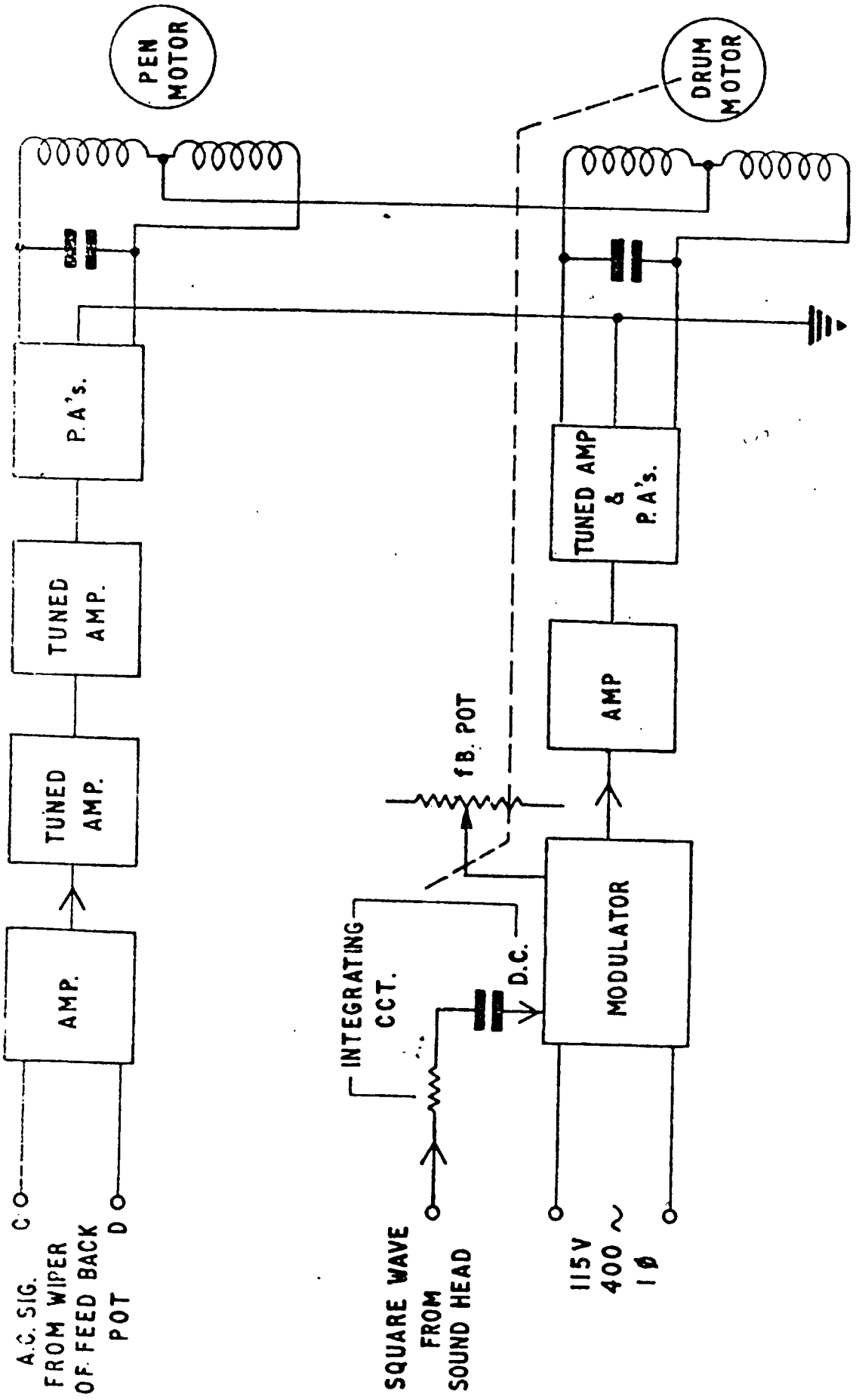
# SONAR TYPE 2004
## OVERALL BLOCK DIAGRAM

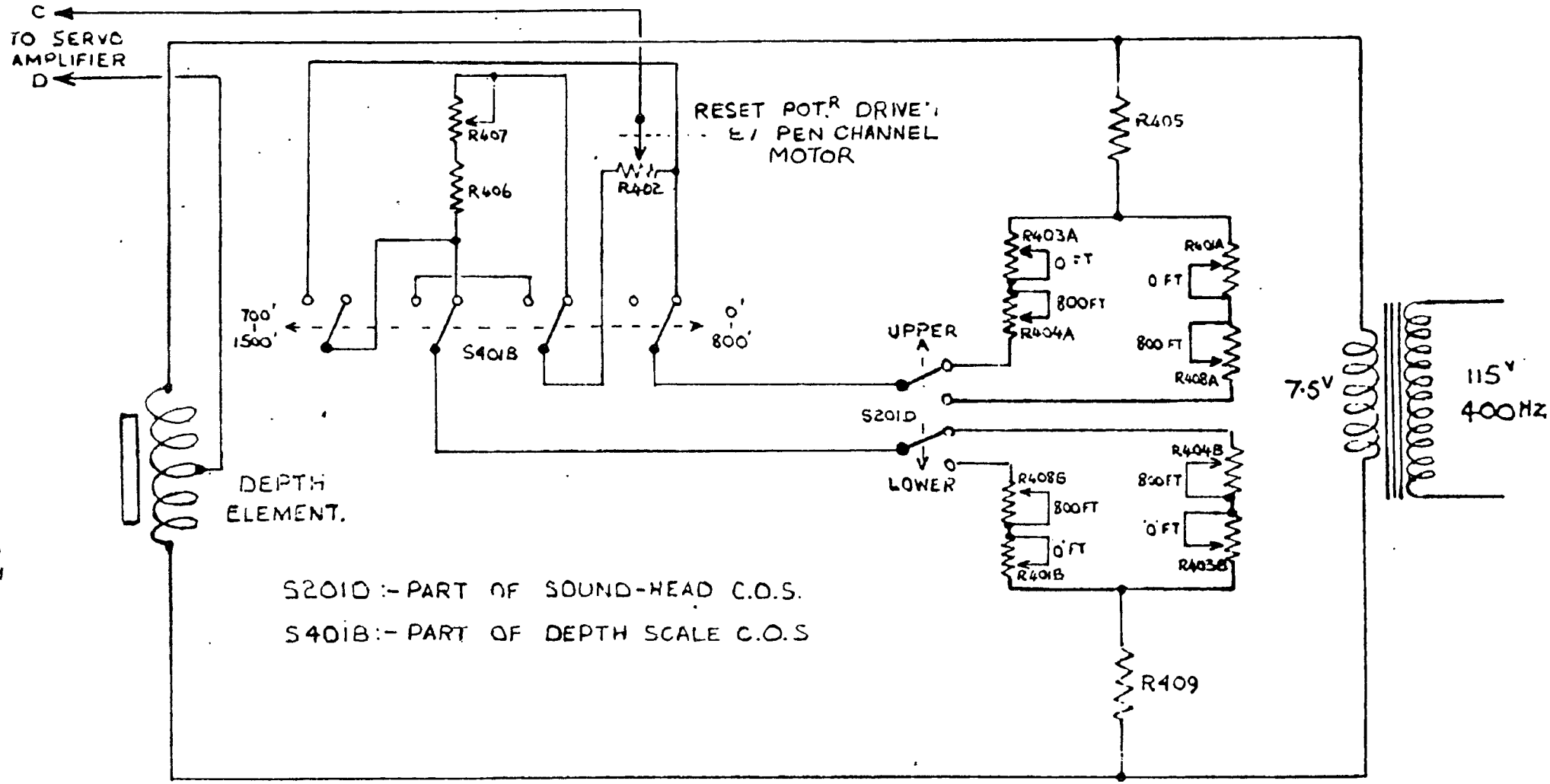


# SONAR TYPE 2004 — MODULATOR OPERATION



# SONAR TYPE 2004
## RECORDER BLOCK DIAGRAM



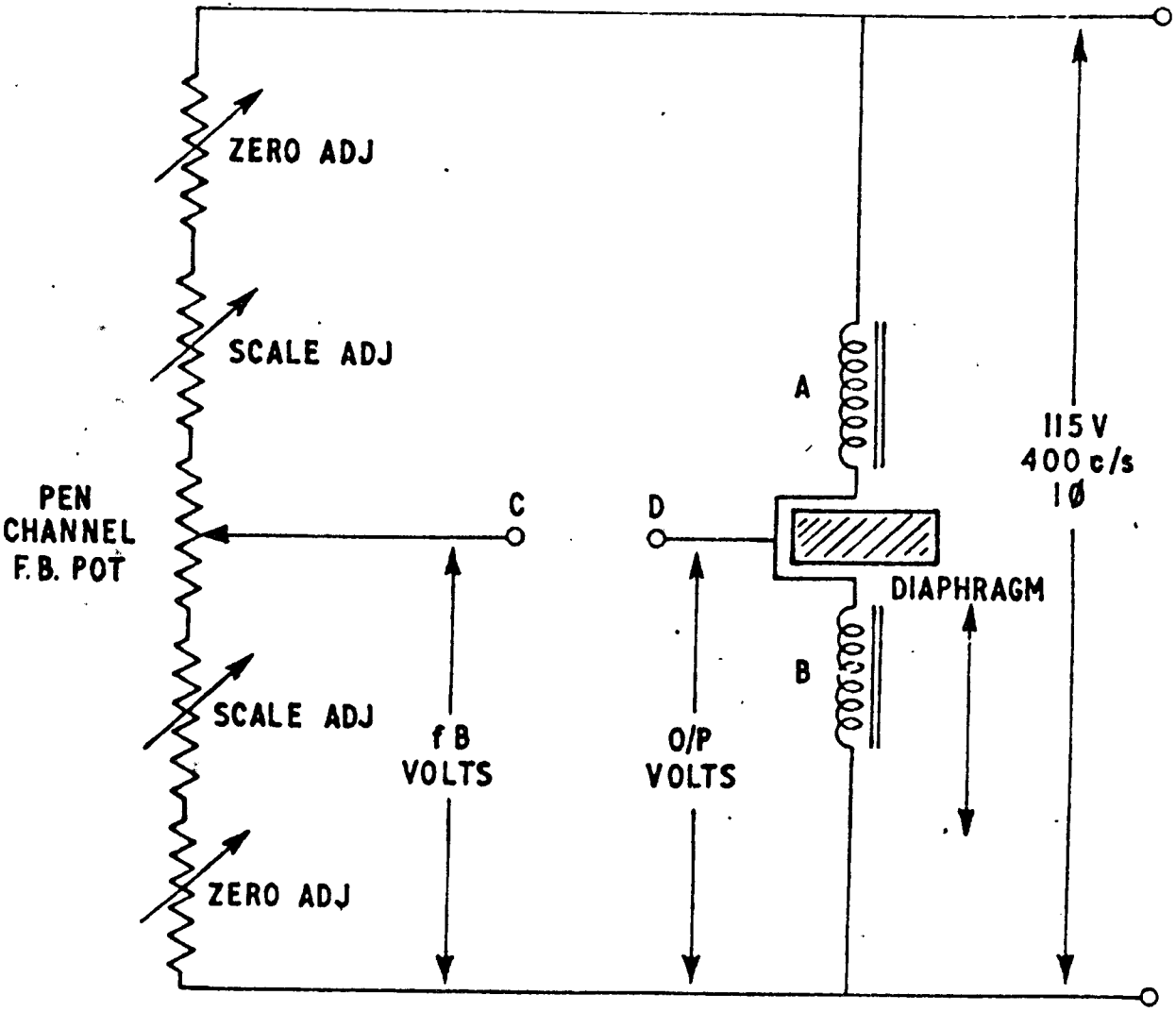



SONAR TYPE 2004. DEPTH CIRCUIT.

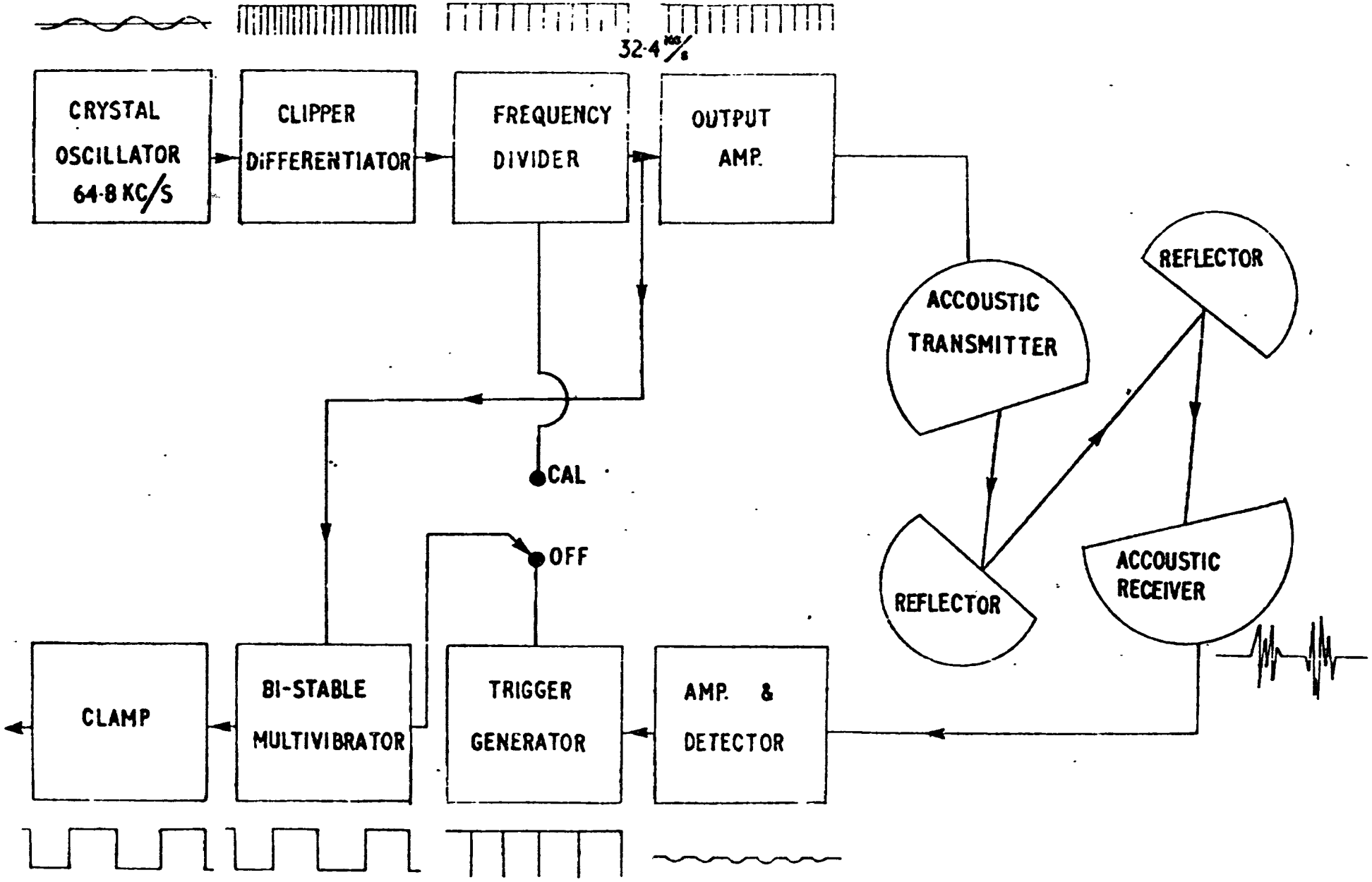
FIG. 5.

# SONAR TYPE 2004

## DEPTH ELEMENT SIMPLIFIED SCHEMATIC



# SOUND HEAD FUNCTIONAL BLOCK (SONAR TYPE 2004)



# CHAPTER 2

# SONAR 2018

## CONTENTS


| | Para |
|---|---|
| References | 1 |
| Function | 2 |
| Power Supplies | 3 |
| Major Components | 4 |
| Fault Finding | 5 |
| The Compression Theory | 6 |
| Onboard Spares | 7 |
| Maintenance | 8 |


## ANNEX


| | | Page |
|---|---|---|
| Annex A | Sweep Generator | ANN 2A.1 - 2A.10 |


## TABLE


| Table No | | Page |
|---|---|---|
| 2.1 | Threshold Test & Voltage Levels | 2.7 |


## ILLUSTRATIONS


| Fig | | Page |
|---|---|---|
| 2.1 | Circuit Diagram Sonar 2018 | 2.2 |
| 2.2 | Time Compression | (2.9<br>(2.10 |

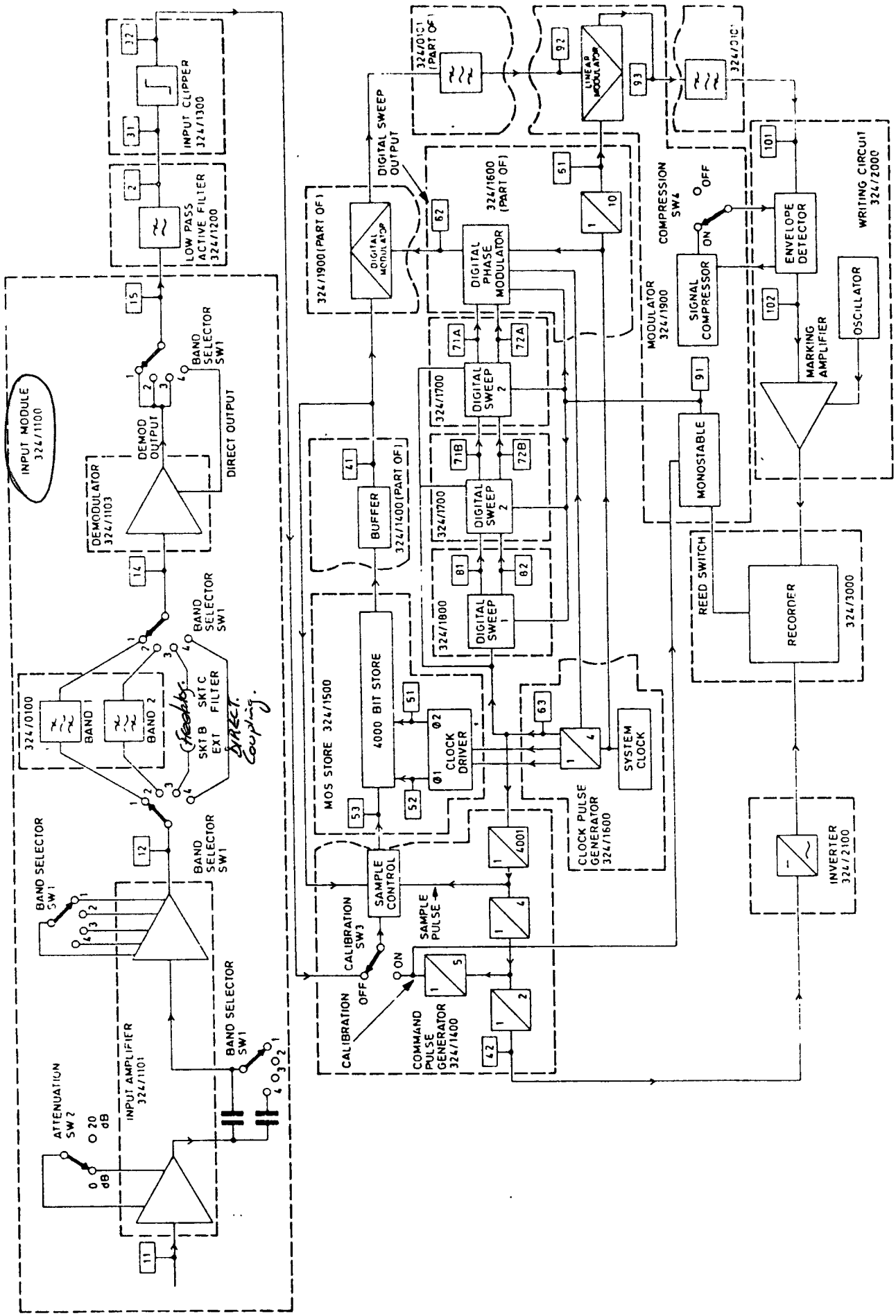
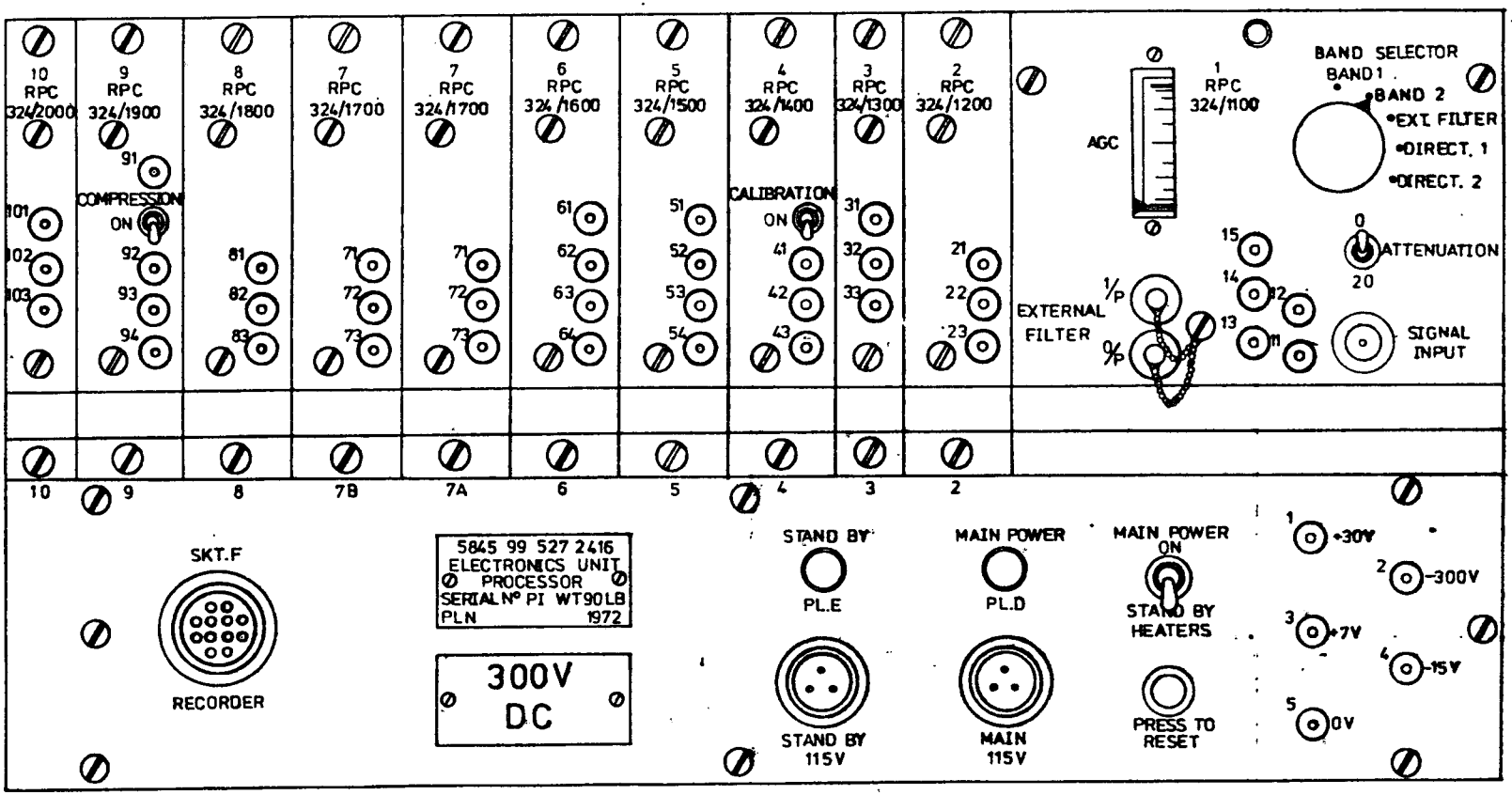



FIG 2.1 SONAR 2018 CIRCUIT DIAGRAM




| ISSUE | DATE | DESCRIPTION OF CHANGE | CONTR. REF. |
|---|---|---|---|
| 1 | JULY 79 | ORIGINAL ISSUE | |

TITLE: SONAR 2018 ELECTRONICS UNIT FRONT PANEL LAYOUT

SERVICE DRAWING NUMBER: ANNEX B TO DWED 8489

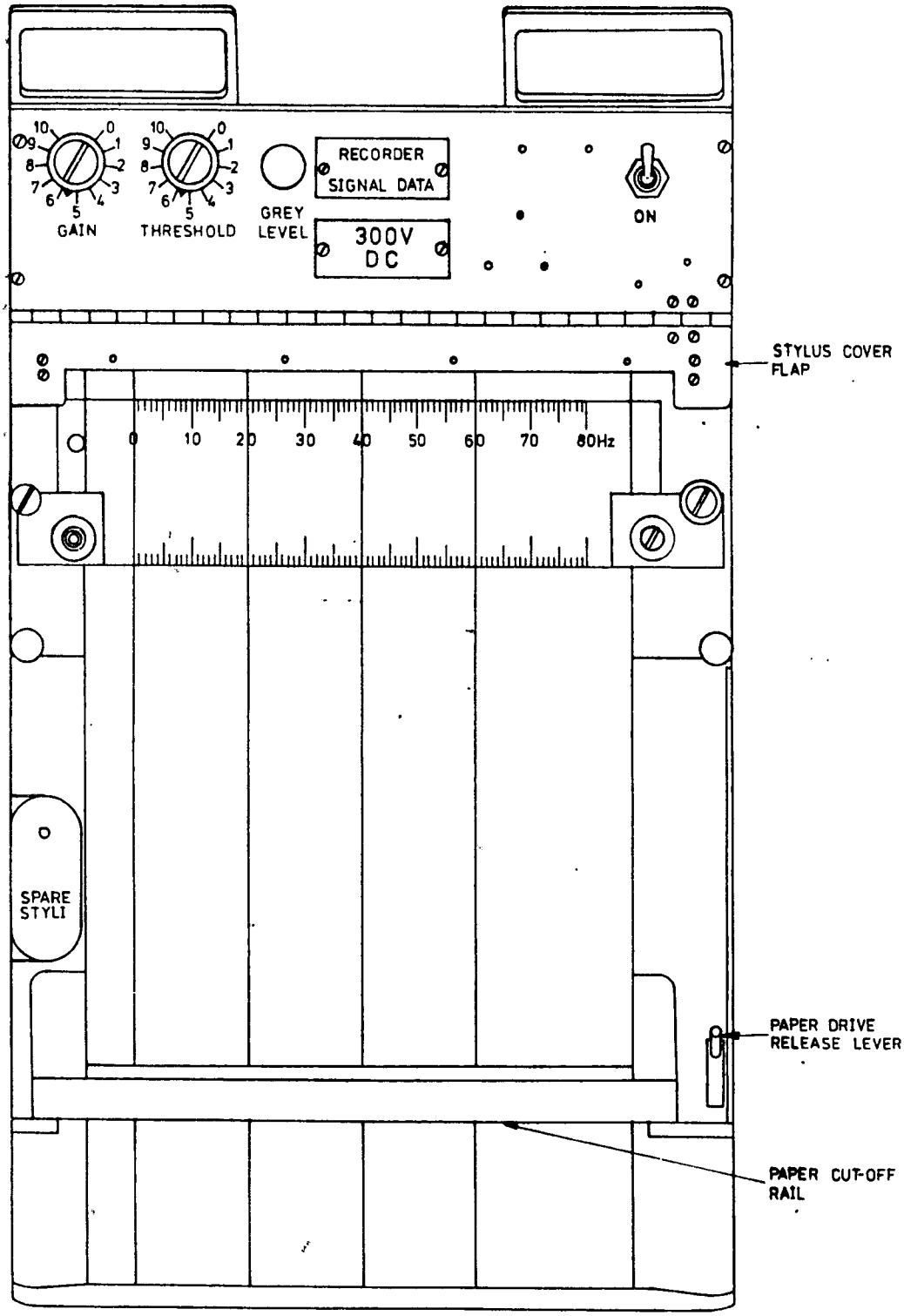
SHT. NO. 1

PUNCH CARD TITLE

FORM NO. TD 107

| SYSTEM CABLE REF. | CABLE Nos ALLOCATED TO THIS SHEET : TO | INDICATES A CABLE WHICH PENETRATES AN AIR OR WATERTIGHT B/HEAD OR DECK | USED CABLE No | UNUSED CABLE No | 23 DELETED CABLE No NOT TO BE RE-USED |
|---|---|---|---|---|---|

| ISSUE | DATE | DESCRIPTION OF CHANGE | CONTR. REF. |
|---|---|---|---|
| 1 | JULY 79 | ORIGINAL ISSUE | |




TITLE
SONAR 2018
DISPLAY RECORDER LAYOUT

PUNCH CARD TITLE

SERVICE DRAWING NUMBER
ANNEX A TO
DWED 8489

SHT. NO. 1

ANNEX A TO DWED 8489

# CHAPTER 2

## SONAR TYPE 2018

### 1. REFERENCES

Books of Reference - CB 5060(1), CB 5060(2), CB 5060(Mods).

### 2. FUNCTION

Sonar Type 2018 is a Spectrum Analyser for use with submarine passive sonars. The function of the equipment is to generate continuous, intensity-modulated, frequency-time plots of signals derived from existing sonar receivers, so as to allow visual detection of spectral lines and the measurement of their frequency relationships. The equipment is primarily intended for the analysis of discrete-frequency amplitude modulation of noise.

#### Processing and Analysis Bands

There are two bands, known as Band 1 and Band 2. The envelope of one or the other of these high frequency bands is detected and then analysed in a Processing Band having a certain bandwidth.

Another band is available which is an input frequency band having the same bandwidth as Band 1 or Band 2 after demodulation is analysed. Certain reservations apply to the use of this facility (See CB 5060(1) Part 1, Chapter 2, Section 5).

Provision is made for connecting an external filter to the equipment so that Bands not covered by Band 1 or Band 2 can be used. This facility is not made use of in RN vessels.

### 3. POWER SUPPLIES

Main 115V plus or minus 10% 48 Hz to65 Hz
Standby 115V plus or minus 10% to 65 Hz.

### 4. MAJOR COMPONENTS

#### a. Input Module

The Input Module performs the selection and initial processing of the input signal(s). The Input Module consists of the following parts:

i. A pre amplifier whose gain is controlled by the 0-20 dB Attenuation Switch.

ii. An amplifier whose gain is changed according to the input band selected.

iii. Band selection filters to select the frequency to be analysed.

iv. An AGC circuit to stabilise the output level.

v. A demodulator for extracting modulation on the input noise.

i. and ii. form the input amplifier, iv. and v. form the demodulator.

b. Signal Input and Input Amplifier

The four position Band Selector Switch SW1 which is a five gauged switch, selects the mode of operation.

Position 1 Band 1 800Hz TO 2000Hz
2 Band 2 2000Hz to 4000Hz
3 External Filter
4 Direct

No whitening circuits are incorporated in the input circuits.

c. Low Pass Active Filter

The selected output from the demodulator is passed into the Low Pass Active Filter. This filter acts as the processing band filter for the analyser.

d. Input Clipper

The Input Clipper consists of three stages:

i. Buffer amplifier.

ii. High gain amplifier.

iii. Voltage Comparator.

The output of the Input Clipper will be sign-bit information representative of the frequency of the output of the Low Pass Active Filter. This output will be applied to a Sample Control Gate via a Calibration Switch.

e. Time Compression Object

The object of Time Compression is to be able to increase the value of an input signal to a higher value which will be representative of the original signal input. Any increase or decrease of frequency of the original signal input (in a logical form) will have a corresponding affect at the output of the Time Compressor. The object of this is to be

able to display a frequency of certain value which may be followed immediately by another frequency and although only having a small separation on a display in Hz, will in actual fact have a separation in the region of kHz.

eg: 10 Hz = 10 kHz
11 Hz = 11 kHz

Display separation - 11 Hz - 10 Hz = 1 Hz
Actual Frequency Separation - 11 kHz - 10 kHz = 1 kHz.

f. Digital Sweep Generator

A sweep frequency is produced by a Digital Sweep Generator starting at f1 and increasing linearly with time to f2. This sweep frequency increase will correspond to the stylus traverse across the width of the recorder, and both are phased together by the operation of a magnet mounted on the stylus carriage passing a set of reed contacts as the stylus moves across the paper. This reed switch will control the operation of a monostable which in turn determines when the Digital Sweep Generator will commence its sweep at f1. The output of the Digital Sweep Generator is applied as an input to the Digital Modulator.

g. Digital Modulator

The output of the 4000 Bit MOS Store is applied, via a Buffer Amplifier for matching, as an input to a Digital Modulator.

The Digital Modulator is a double-balanced modulator, generating upper and lower sidebands. The output from the Digital Modulator contains swept frequency sideband components that correspond to the frequencies present in the signal analysis. The lower sideband components from the Digital Modulator are selected as they sweep through the Narrow Bandpass Filter following the Digital Modulator.

h. Filter

The signal is passed by the filter at a time depending upon the value of the original signal input, the value of the sweep frequency and the position of the stylus so that the pen marking the paper is correctly positioned in relation to the scale which corresponds to the original signal input when all the above factors are phased together.

j. Linear Modulator

The output of the filter is applied to a Linear Modulator, which also has a frequency input originating from the

Crystal Controlled System Clock via Divide Circuits. The output of the Linear Modulator will be the sum and difference of the two signal inputs.

k. Filter

The difference signal only will be passed by a narrow band filter. This filter is the analysing filter for the 2018 equipment.

The output of the analysing filter consists of a carrier waveform amplitude modulated by pulses whose delays on the sweep start are proportional to their corresponding signal frequencies. This signal is fed into the writing circuits.

l. Writing Circuits

The input signal is connected to a voltage-to-current converter, the output of which is envelope detected. The envelope detector has a variable resistive load that controls the gain, and a bias or threshold arrangement that suppresses the lower levels of the signal, allowing only the larger peaks to pass. These controls, called the Gain and Threshold oontrols are located on the recorder. The envelope detector output controls the pulse width of a variable-width pulse generator that is triggered by a square wave oscillator. The pulse generator drives a high voltage pulse amplifier whose output pulses have an amplitude of approximately 300V (0 to -300V). These output pulses constitute the writing signal that is passed to the recorder.

m. Compression Circuit

The input to the envelope detector is also connected via a switch to a compression circuit. When the compression circuit is set to on, the gain of the envelope detector is partially contolled by the shunting effect of a transistor. The presence of a large pulse in the compressor will temporarily reduce the gain of the envelope detector so that the same pulse passing through the latter will have its peak value reduced and its fall time decreased, thus enhancing the probability of detecting a small pulse immediately following a large one, or improving the resolution between two closely spaced large pulses.

n. Invertor

The recorder stylus and paper drive motors derive their supplies from an Inverter which is controlled via divide circuits from the Crystal Controlled System Clock.

## 5. FAULT FINDING

The 2018 equipment is supplied with its own test set, which when used in conjunction with the SM 111 oscilloscope and Handbook CD 5060(1) Part 3C should enable the maintainer to isolate and rectify faults as they arise in the equipment.

| Test Set | | | | | | 2018 Settings | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mode Selector | Relative S/N dB | Tone Frequency Hz | Side Bands Spacing Hz | Side Bands Ref Tone | O/P Attn dB | Band Selector | Attenuation dB | Calibration | Compression |
| D.Lo | 4 | 40 | 0.4 | OFF | 20 | Band 1 | 0 | OFF | OFF |
| D.Hi | 4 | 40 | 0.4 | OFF | 20 | Band 2 | 0 | OFF | OFF |
| Direct 1 | 4 | 40 | 0.4 | OFF | 20 | Direct | 0 | OFF | OFF |

| DC Voltage Levels and Test Points | | | | |
|---|---|---|---|---|
| Test Point | 0V | Nominal Voltage | Tolerance Limits | |
| TP1 | TP5 | +30V | 29V to 31V | On rear of main Heat Sink on PSU1 |
| TP3 | TP5 | + 7V | 6.5V to 7.5V | |
| TP4 | TP5 | -15V | 14V to 16V | |
| TP2 | TP5 | -300V | -290V to 310V | Front Panel PSU2 |

TABLE 2.1

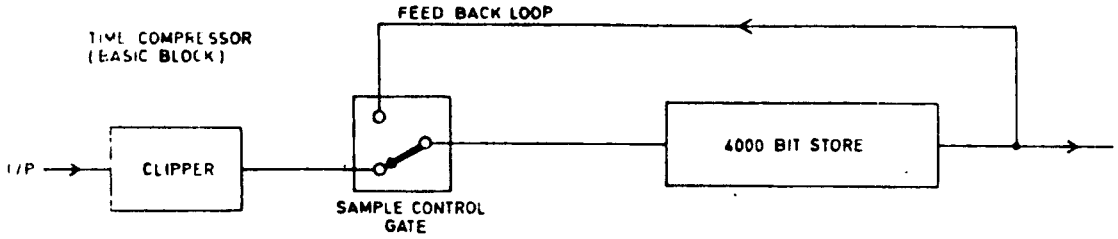
THRESHOLD TEST & VOLTAGE LEVELS

## 6. TIME COMPRESSION (THEORY)

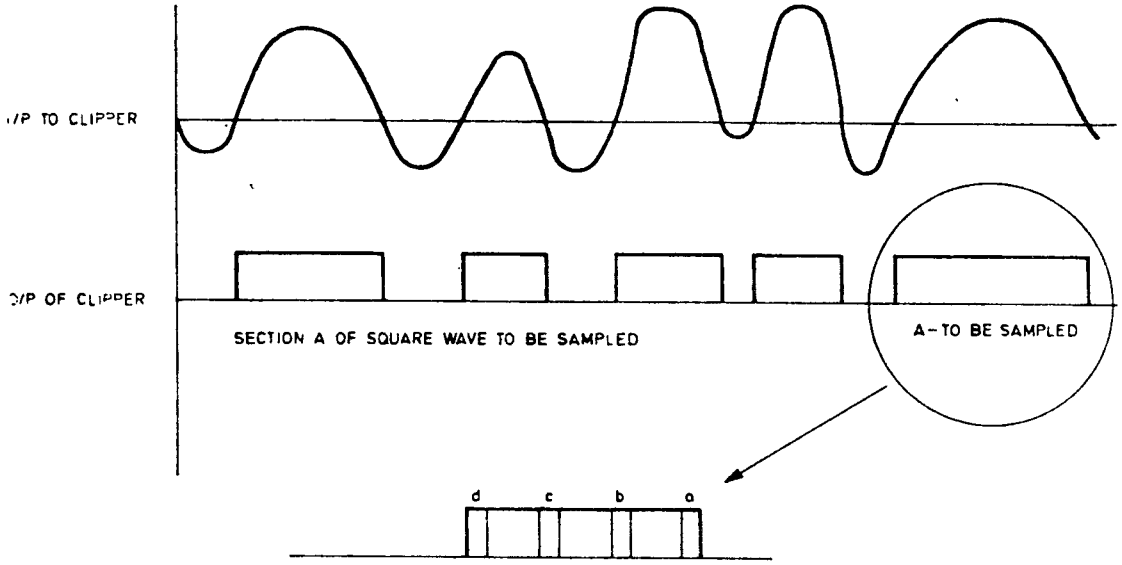
A portion of a square wave, which is the square wave of the original signal input, is held in a Sample Control Gate. It is sampled by a very high number of pulses all the time it is going positive. The number of pulses will now represent that frequency. The time between the leading edges of any pair of pulses is always the same - eg: 2.5 milli seconds.

A pulse is accelerated through a 4000 Bit Store and fed back, by a feed-back loop, to where it started in 2.51 milli seconds. When the next pulse is about to be passed through the 4000 Bit Store, the pulse being fed back, will position itself one pulse length in front of the incoming pulse. The two pulses will be accelerated through the 4000 Bit Store together and will be fed back to the input in 2.51 milli secs. The first pulse will now be positioned two pulse lengths in front of the next incoming pulse. The three pulses will now be accelerated through the 4000 Bit Store and so on. Thereby, we have compressed the time between the pulses down to a minimum.

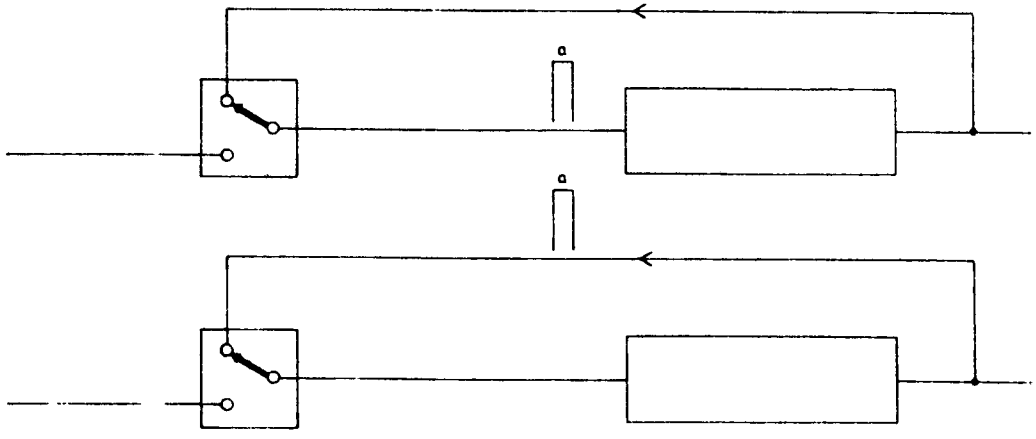
This process will continue for a predetermined length of time, after which another portion of the square wave will be processed in a similar manner, so that up to date processed information is continually being fed into the system. The flow of pulses through the feedback loop, or 4000 Bit MOS Store is controlled by a two phase clock driver which, in turn, is controlled by a crystal controlled system clock via a divide circuit. This same crystal controlled system clock also operates the Sample Control Gate and Calibration Frequencies via various divide circuits, the value of which will be determined by what is required for that particular circuit in the system.




ELECTRONIC SWITCH OF SAMPLE CONTROL GATE IN POSITION TO ACCEPT CLIPPED SIGNAL FROM THE CLIPPER




PULSES ADDED WHEN SQUARE WAVE GOES POSITIVE. TIME PERIOD BETWEEN LEADING EDGES OF EACH PAIR OF PULSES EQUALS 2·5 MILLI SECONDS.




ELECTRONIC SWITCH OF SAMPLE CONTROL GATE IN POSITION TO ACCEPT RECYCLED PULSE

FIG. 2.2(a) TIME COMPRESSION

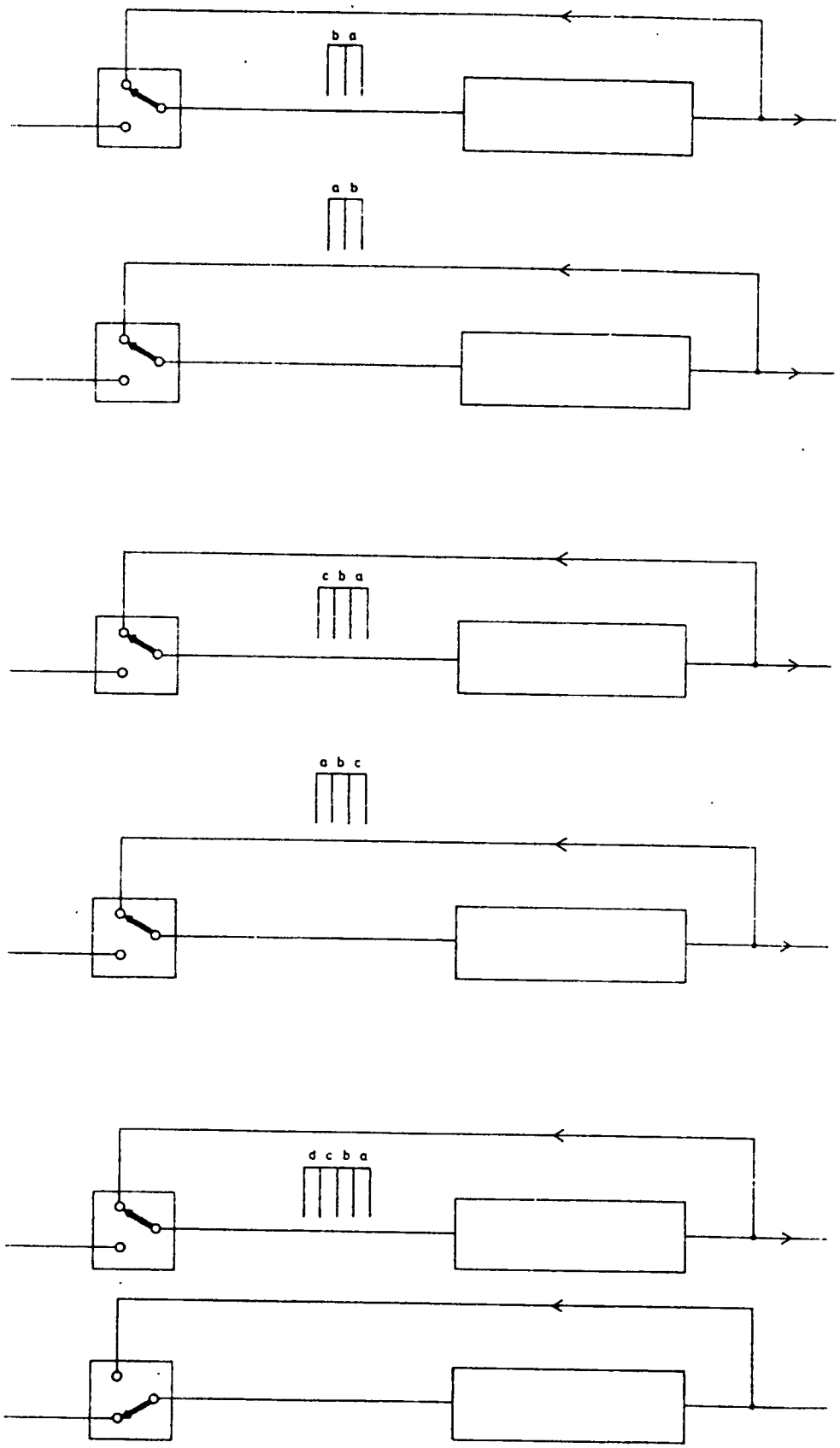



FIG 2.2(b) TIME COMPRESSION

8. MAINTENANCE

NOTES: (1) Sonar Type 2018 is a commercial equipment that has not been manufactured to the normal rugged Service standards. It is therefore essential that it is used and maintained with care, if it is to give reliable service in the submarine environment.

(2) WARNING:

The passage of current through the recorder paper causes the release of toxic fumes and solid particles. These are extracted by the fume filter, however, if the filter is not changed regularly as below, it may break down and thereby endanger health.

Operators Checks (CB 5060(1) and (2))

Four hourly check frequency calibration.

Every paper reel change:

a. Clean Stylus cleaning pad
b. Clean write roller
c. Renew stylus
d. Reload stylus holder

Weekly

W1 Clean pressure roller and drive roller

W2 Clean paper roll cavity

Maintainer Checks:

W1 Check threshold

W2 Clean and lubricate stylus carriage rod guides

Monthly:

M1 Replace stylus cleaning pad

M2 Change fume filter

Annually:

A1 a. Remove complete electronic assembly from the electronic unit and clean the cabinet with a soft brush.

b. Clean plugs with clean linen and ZX 33.

c. Examine all wiring, components and insulation for damage and deterioration.

d. Check all nuts, bolts and screws etc are tight.

e. Replace the electronics assembly and check all PCB's are secure.

A2 Check that the resistance to earth of the chassis of each unit is less than 0.1 ohm.

Bi-Annually:

2A1 Check that the fume extraction unit fan motors run freely and that its field insulation is above 50 ohms to earth.

Refit:

R1 Remove complete set and place in a warm dry store. Return the recorder and any units below the latest Mod state and demand new.

R2 Dockyard reinstall the set, new recorder and latest Mod state units (See R1), and set to work in accordance with CB 5060(1) Part 6A.

R3 Carry out HAT in accordance with Test Form.

Post Refit:

PR1 Carry out SAT in accordance with Test Form.

2017/2018
ISS 1 3.81

# CHAPTER 2

## ANNEX A

## SWEEP GENERATOR

## CONTENTS


| | Para |
|---|---|
| Components | 1 |
| Digital Phase Modulator | 2 |
| Parabolic Function Generator | 3 |


## ILLUSTRATIONS


| Fig | | Page |
|---|---|---|
| ANN 2A.1 | Block Diagram Digital Processor Block | ANN 2A.2 |
| 2A.2 | Digital Phase Modulation | 2A.4 |
| 2A.3 | Circuit Diagram Digital Phase Modulator | 2A.5 |
| 2A.4 | Digital Phase Modulator Theory | 2A.6 |

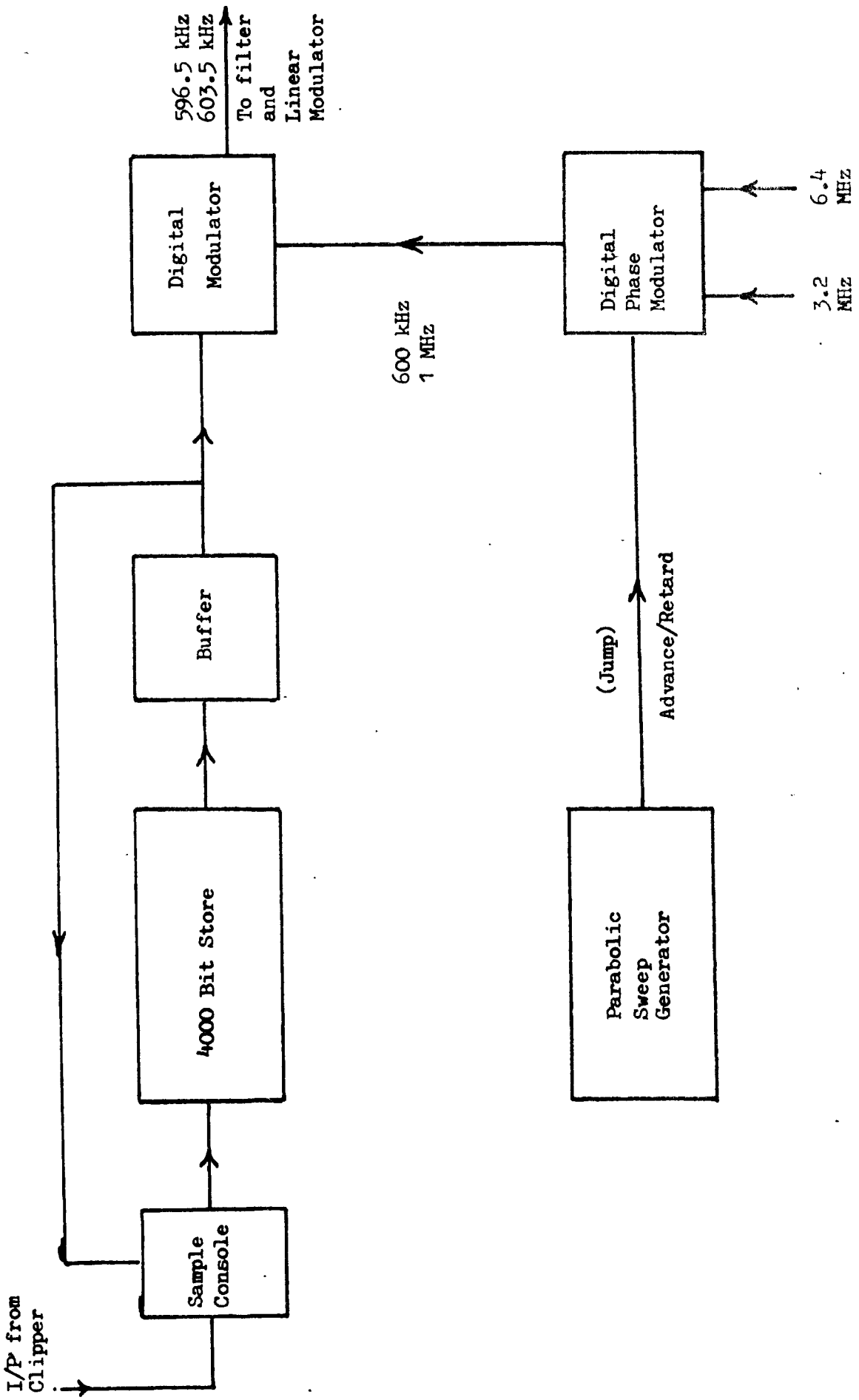



Fig ANN 2A.1 BLOCK DIAGRAM DIGITAL PROCESSOR BLOCK

# CHAPTER 2

## ANNEX A

## SWEEP GENERATOR

1. COMPONENTS

The digital sweep generator consists of two parts.

a. Digital phase modulator.

b. Parabolic function generator.

2. DIGITAL PHASE MODULATOR

a. Function

i. Frequency (F) is an unmodulated square wave (the carrier). The zero crossing of the square wave occur at regular intervals. 1/2F.

ii. The digital phase modulator operates so that, at a given command the time of the next zero crossing is advanced or retarded by a quarter of a period 1/4F (See Fig Ann 2A-2).

iii. If the advance command is given at every crossing, all the intervals will be reduced to 1/4F a frequency of 2F.
If the retard command is given at every crossing, all the intervals will give uniform crossings at 3/4F, a frequency of 2/3F.

iv. Any frequency between the limits of 2/3F and 2F can be approximated to, by a suitably spaced sequence of advanced and retarded signals.

b. Problems

i. (1) The modulation of the carrier in steps of 1/4F produces a spectrum of unwanted sweep frequencies, as well as the required sweep frequency.

(2) The larger 1/4F is in hertz, the greater is the spectrum of unwanted sweep frequencies. ie 1/4F is a measure of this unwanted spectrum. This effect is lessoned by initially operating on a carrier (Fc) which m times the frequency required. (m is any power of 2).

Fc = mF (in 2018 m = 4).

The step is now m times smaller (1/4mF). Hence the unwanted is decreased by a factor of m (4).

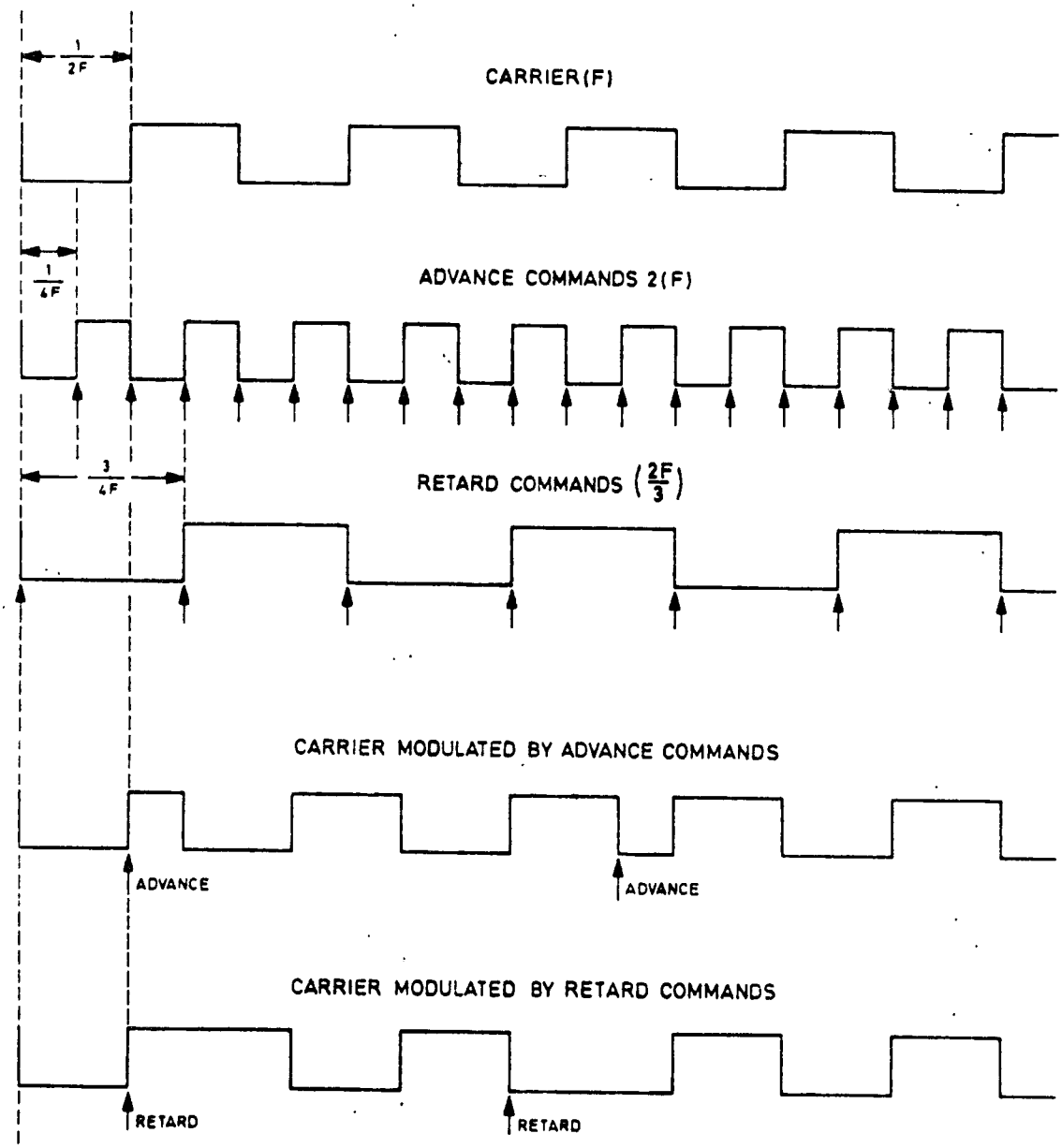



FIG ANN 2A-2 DIGITAL PHASE MODULATOR

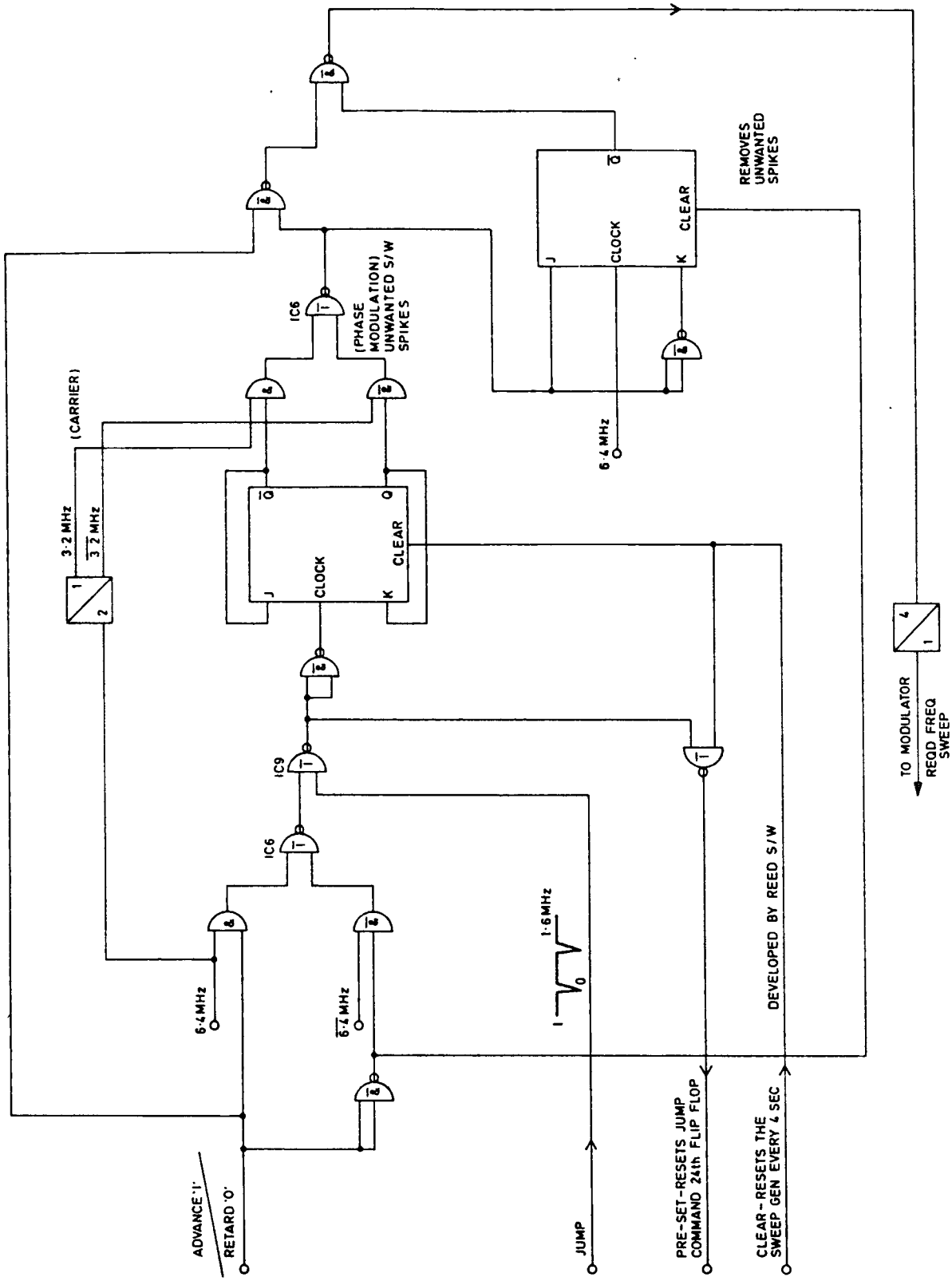



FIG ANN 2A-3 BLOCK DIAGRAM DIGITAL PHASE MODULATOR

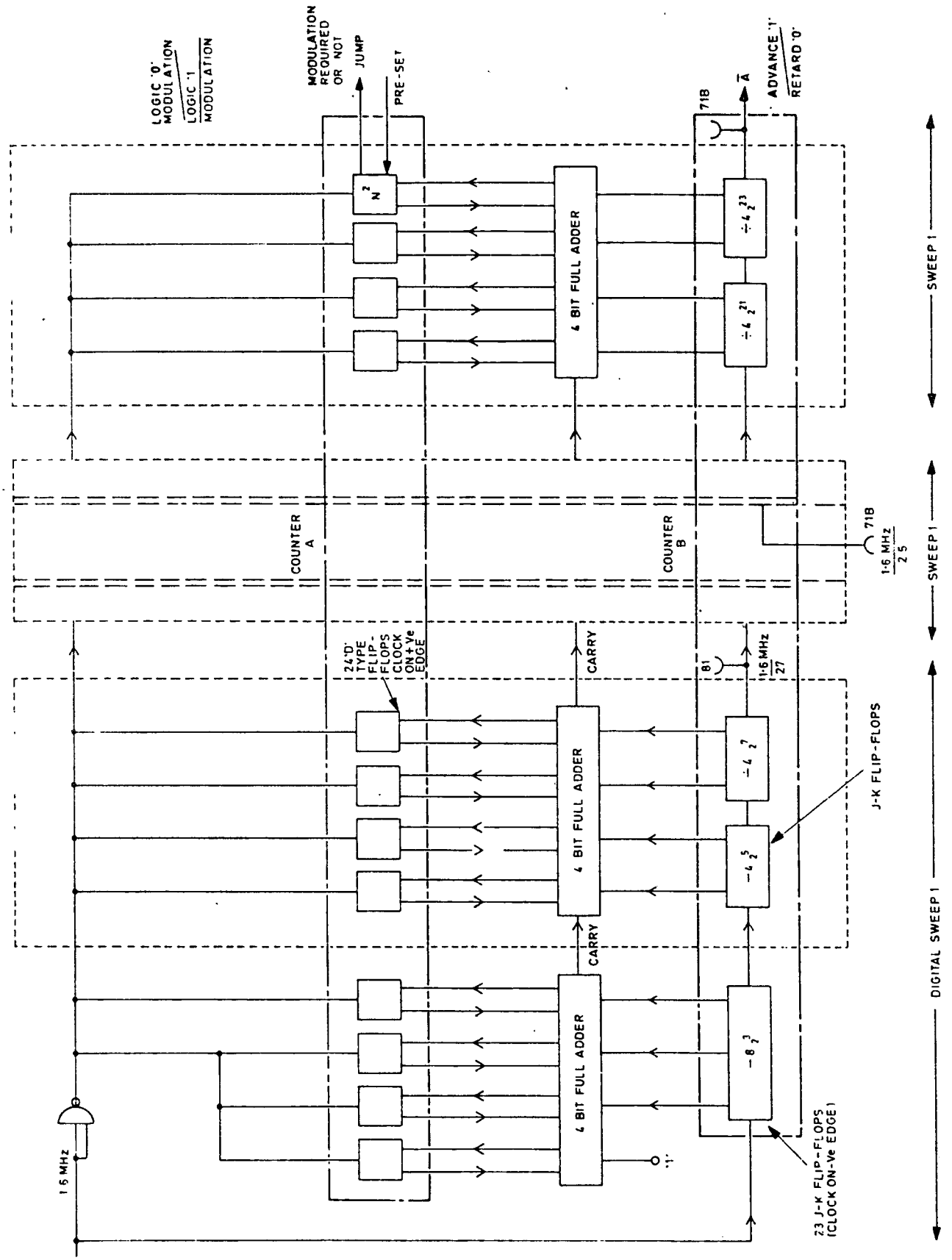



FIG ANN 2A 4 DIGITAL PHASE MODULATOR - THEORY

ii. The output of the digital phase modulator is divided by m to give the required sweep frequency.

c. Modulation

Let P be the function representing the degree of modulation required to cover the frequencies 2/3F and 2F.

P = +1 P = 0 P = -1

P = +1 The zero crossing of the carrier (mF) is advanced by a quarter period.

P = -1 The zero crossing of the carrier (mF) is retarded by a quarter period.

P = 0 The carier is unchanged.

The sequence of binary signals is generated by the parabolic generator.

3. PARABOLIC FUNCTION GENERATOR

The generator produces a number, $N^2$, from an input of N pulses.

Consider two binary counters: Counter A with S+1 cells.
Counter B with S cells.

Counters are lined up from the right end, ie the most significant end.

| | | Total |
|---|---|---|
| Counter A | 0 0 0 0 ($2^0$ $2^1$ $2^2$ $2^3$) | 0 |
| Counter B | 0 0 0 ($2^1$ $2^2$ $2^3$) | 0 |

To obtain a number $N^2$ from N counts into the counters the number in the counter B is added to the number in counter A, the result stored in counter A, and a pulse fed into both counters. For example assume $N^2$ is already in counter A and the number 2N is in counter B the:

| Operation | Counter A | Counter B |
|---|---|---|
| Initial positions | $N^2$ | 2N |
| (1) Add B to A | $N^2+2N$ | 2N |
| (2) Feed 1 pulse to each counter. | $N^2+2N+1$ $= (N+1)$ | 2N=2 $= 2(N+1)$ |

ie: $N^2$ has increased to $(N+1)^2$.

| | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | s+1 | | |
| Counter A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Counter B | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Counter A | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N=1 | 1 |
| FEED 1 pulse | | | | | | | | | | | |
| Counter B | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 2 |
| Add A Counter A | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | N=2 | 3+1=4 |
| to B & clock in 1 pulse | | | | | | | | | | | |
| Counter B | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 2+2=4 |
| Add A Counter A | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | N=3 | 8+1=9 |
| to B & clock in 1 pulse | | | | | | | | | | | |
| Counter B | | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 4+2=6 |

Clearly Counter A produces $N^2$ from N inputs ) USED TO DRIVE DIGITAL PHASE
Counter B produces 2N from N inputs ) MODULATOR

For S cells in counter B and assuming the number is initially zero, the number of pulses into counter B to produce its maximum number is $2^S$. The counter then returns to zero, ie it is cyclic with period $2^S$ counts.

If N is the number of counts in a frequency range F and m is the divisor (2018 = 4) the number of counts at the output of the digital phase modulator circuit is mN.

$$(1) \quad \text{Hence } mN = 2^S$$

The number of counts N in a frequency range $\Delta$ F over a time interval T is given by:

$$(2) \quad N = TDF$$

For T -S secs and $\Delta F = 400$ kHz

$$N = S \times 400 \times 10^3 = 2 \times 10^6.$$

In the type 2018 the divisor m at the output of the digital phase modulator is 4.

Therefore $mN = 4 \times 2 \times 10^6 = 8 \times 10^6$

$$mN = 2^S$$

$$2^S = 8 \times 10^6$$

$2^S = 2^{23}$

$2^{s+1} = 2^{24}$

Hence Counter B is a 23 stage binary counter.

Counter A is a 24 stage binary counter.

P is a function representing the degree of modulation required to cover the frequencies 2/3F and 2F.

P =+1 Zero crossing of the carrier (mF) is advanced by a $\frac{1}{4}$ period.

P =-1 Zero crossing of the carrier retarded by a $\frac{3}{4}$ period.

P = 0 The carrier is unchanged.

P therefore has three possible values, hence two orders are required to describe the degree of modulation in a "binary form". These orders are called the "JUMP" and "ADVANCED/ RETARD" commands.

The "JUMP" command is given the value logic "1" when no modulation is required, and logic "0" when modulation is required.

The "ADVANCE/RETARD" command is given the value logic "0" when P = -1 (ZERO CROSSING RETARDED) and logic "1" when P = +1 (ZERO CROSSING ADVANCED).

The 24th cell of counter A is used as the "JUMP" command. This digit changes every time $N^2$ increases by $2^{23}$. The 24th cell isset to logic "1" between each count.

At the start of the cycle, the input to the 24th cell is at logic "0" and hence the output of this cell is a logic "0" after the count. Thus the "JUMP" command is logic "0" and the carrier is modulated. The modulation continues until $N^2/2^s$ becomes greater. Ov =to 1. (ie the digit of the 24th cell is a logic "1") when the modulation is interrupted for one count.

As the number of counts increases (ie as N increases) the occurrence of logic "1" in the 24th cell increases and the modulation of the carrier decreases.

The 23rd cell of counter B changes once during a complete cycle, the change occurring at the mid point of the cycle. By setting the 23rd cell initially to logic "0" it corresponds to the "RETARD" command for the first half of the cycle and to the "ADVANCE" command "1" for the second half. Hence the frequency ranges from a low to a high value during the cycle.

(1) $mN = 2^s \qquad N = \frac{2^s}{m}$ eg:

$s = 23 \quad F = 400\ kHz \quad m = 4$

(2) $N = T \quad F \qquad T = \frac{N}{F}$

$T = \frac{2^s}{m} \quad F$

$$T = \frac{2^{23}}{4 \times 400 \times 10^3} = \underline{5.24\ secs}$$

That is 5.24 seconds for the sweep to move through a range of 400 kHz.

The A & B counters are clocked at a frequency Fp.

$$Fp = \frac{2^s}{T} = m \quad F$$

$$Fp = \underline{1.6\ MHz} = \text{clocking rate.}$$

The sweep is required to start at 600 kHz, the centre frequency (F3) of the analysing filter in the system. Hence it would sweep from 600 kHz to 1 MHz in about 5.24 seconds.

For processing band of 80 Hz at the input, a band of 80 x 4001 Hz ie about 320 kHz is produced at the output of the time compressor. Hence a sweep range of 320 kHz is required.

$$\text{Sweep time } ts = \frac{320 \times 5.24}{400} \quad \underline{\quad} \quad \underline{4.2 \text{ seconds}}$$

4.2 secs is the time required to display the complete frequency range on the recorder.

$Fc = mF$ where Fc is the carrier frequency for the digital phase modulator.

$m = 4$

$F$ = the output centre frequency of the sweep.
$\frac{600\ kHz + 1\ MHz}{2} = 800\ kHz.$

$\therefore Fc = 4 \times 800\ kHz = 3.2\ MHz$

(carrier frequency Of the digital phase modulator).

# GENERAL INFORMATION FOR E/S 778.

## GENERAL SERVICE DEPTH RECORDER (GSDR).

Power Supplies:
115V ± 10% , 55Hz ± 6.5 Hz.

Depth Velocity:
Either 4800 or 4920 feet/second.

Depth Range :
2 to 4500 fathoms in three ranges.

TRANSMITTER:

Frequency :
10KHz.

Pulse Width :
1ms on the 225 fathom range.
5ms on the 450 or the 4500 range.

Power :
300 watts maximum. 0 to 50db attenuation in 10db steps.

## BRIDGE UNIT (BU).

Power Supplies:
Same as GSDR.

Depth Velocity:
4920 feet/second.

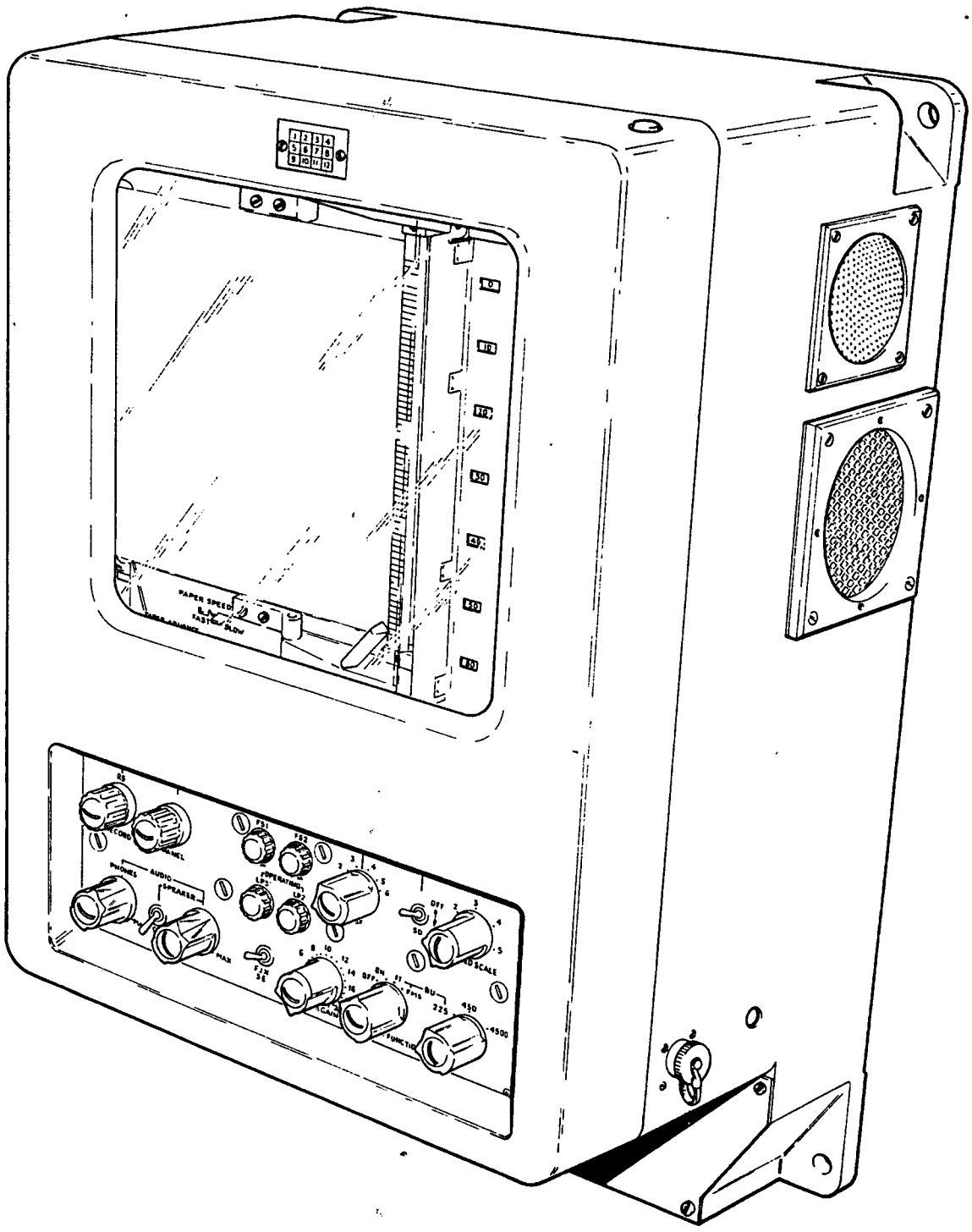
Depth Range :
6 to 99 feet or 6 to 99 fathoms.

TRANSMITTER:

Frequency :
48KHz nominal.

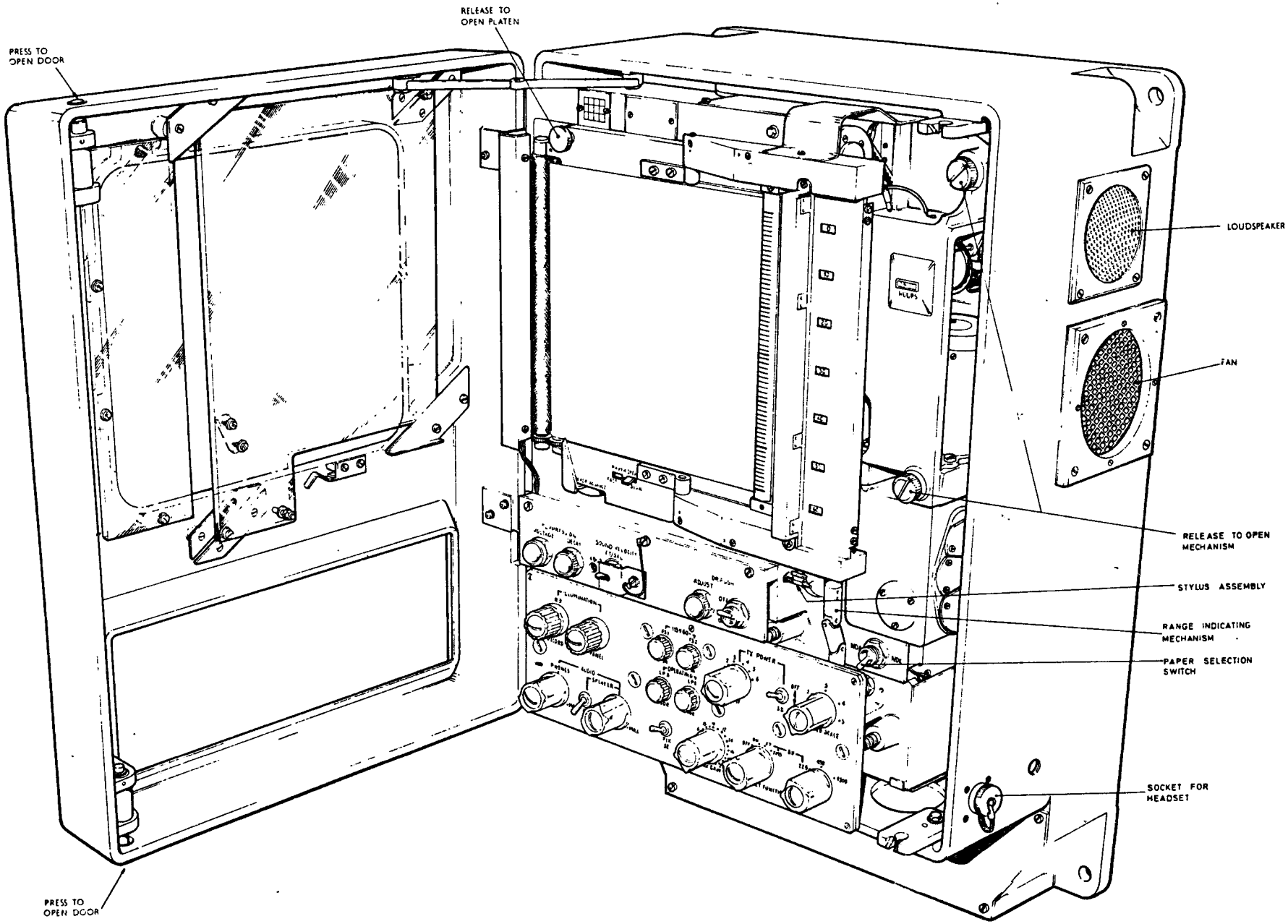
Pulse Width :
200us on "feet" range.
500us on "fathom" range.

Power :
10 watts on feet; 50 watts on fathoms.




GENERAL SERVICE DEPTH RECORDER

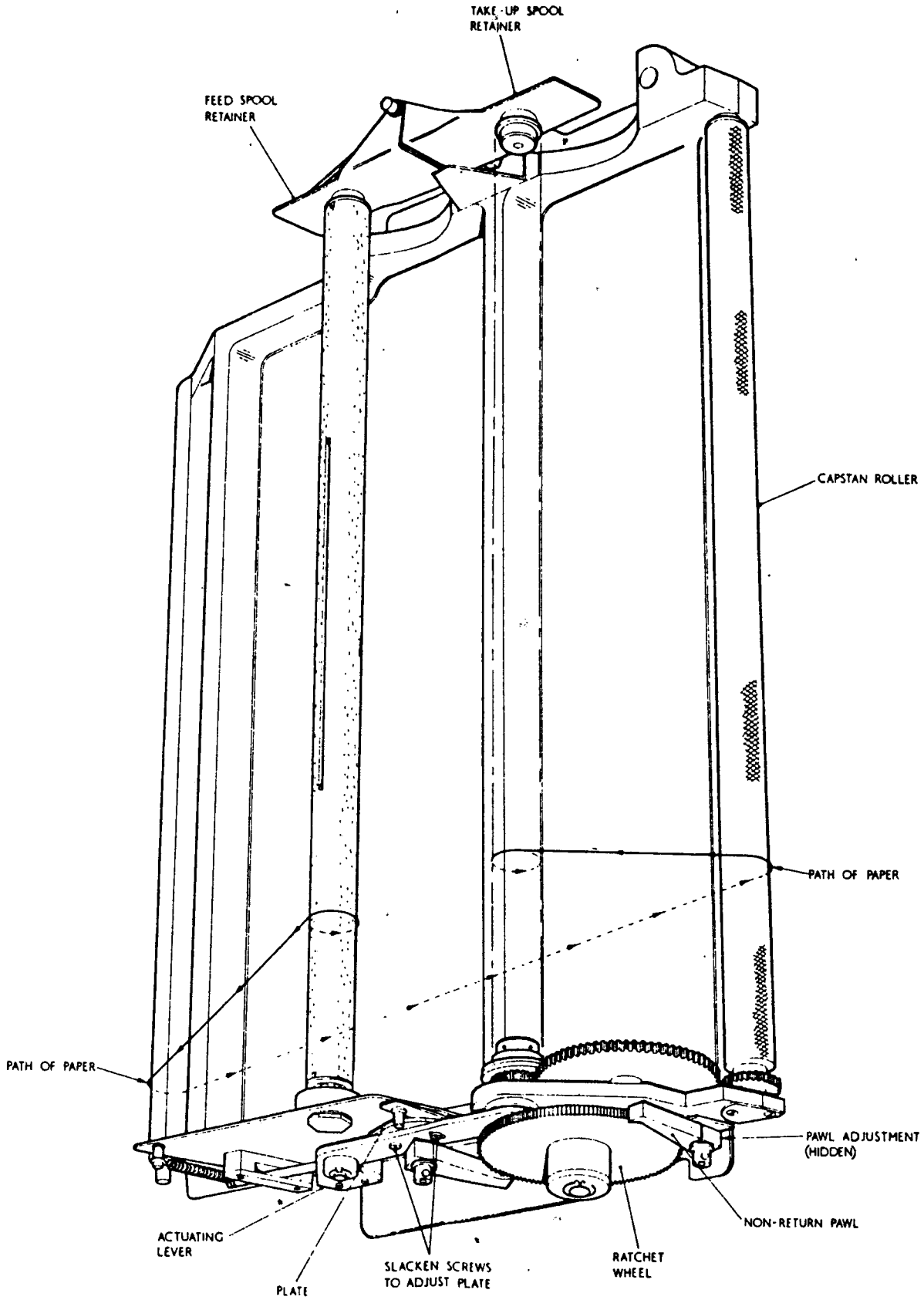
FRONTISPIECE

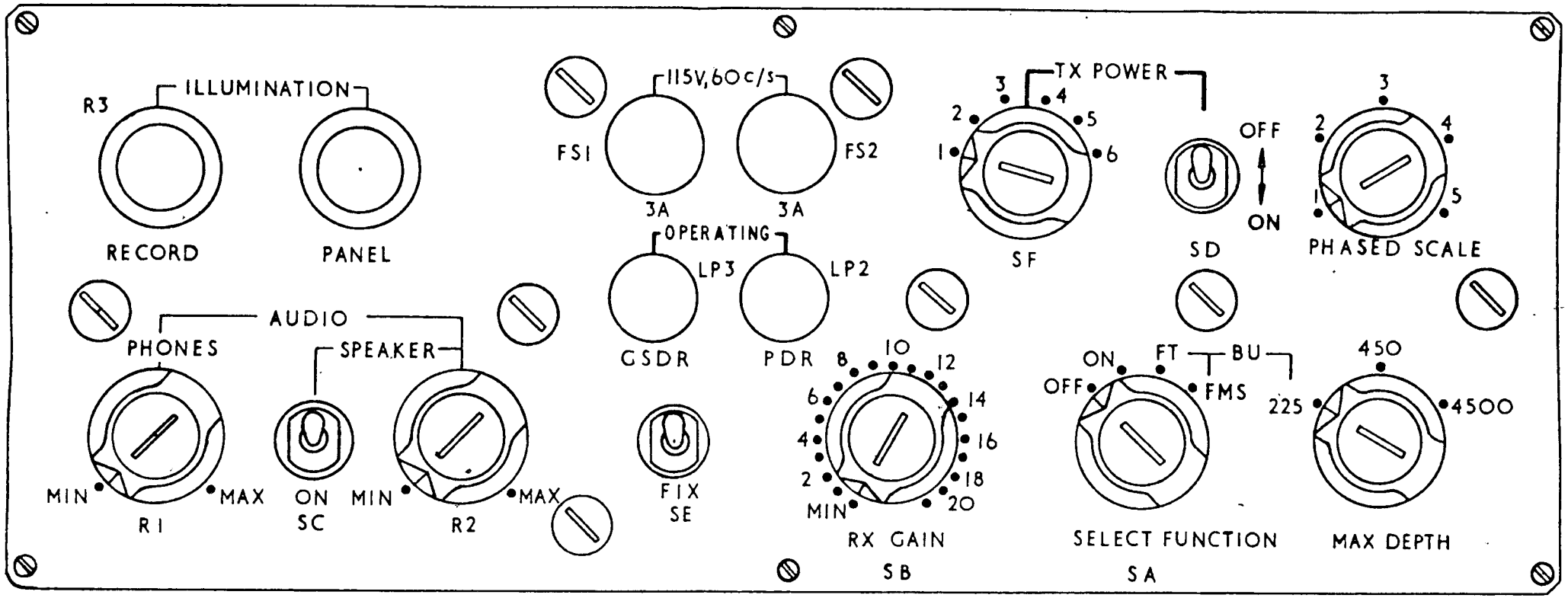



64

FRONT VIEW OF G.S.D.R.

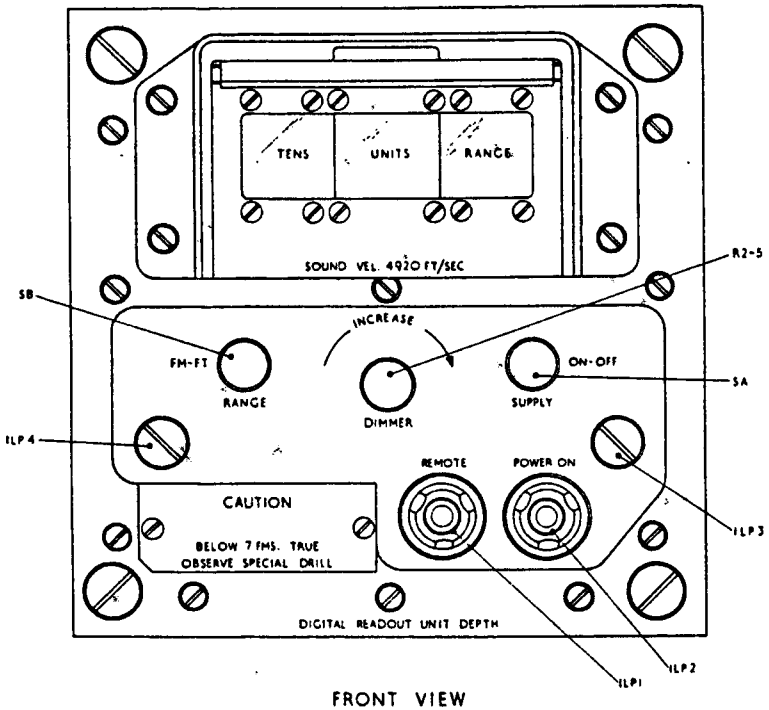
FIG. 1.1


TAKE-UP SPOOL RETAINER
FEED SPOOL RETAINER
CAPSTAN ROLLER
PATH OF PAPER
PATH OF PAPER
PAWL ADJUSTMENT (HIDDEN)
NON-RETURN PAWL
ACTUATING LEVER
PLATE
SLACKEN SCREWS TO ADJUST PLATE
RATCHET WHEEL

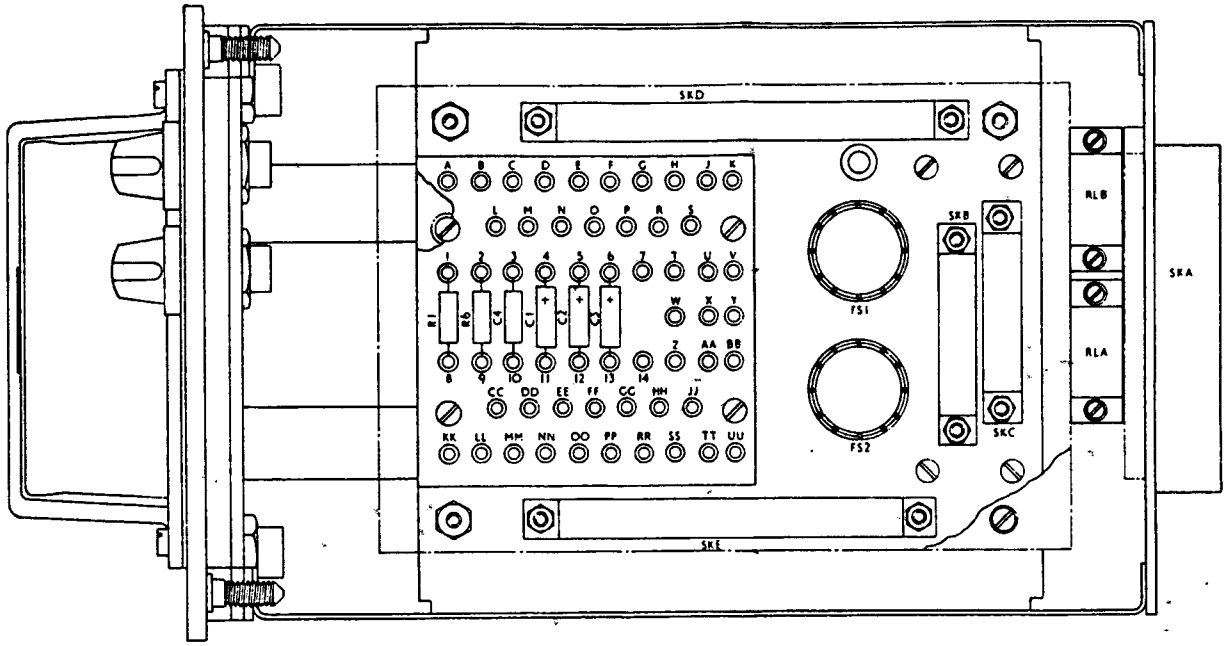



CONTROL PANEL

FIG.2C.1.2.




FRONT VIEW



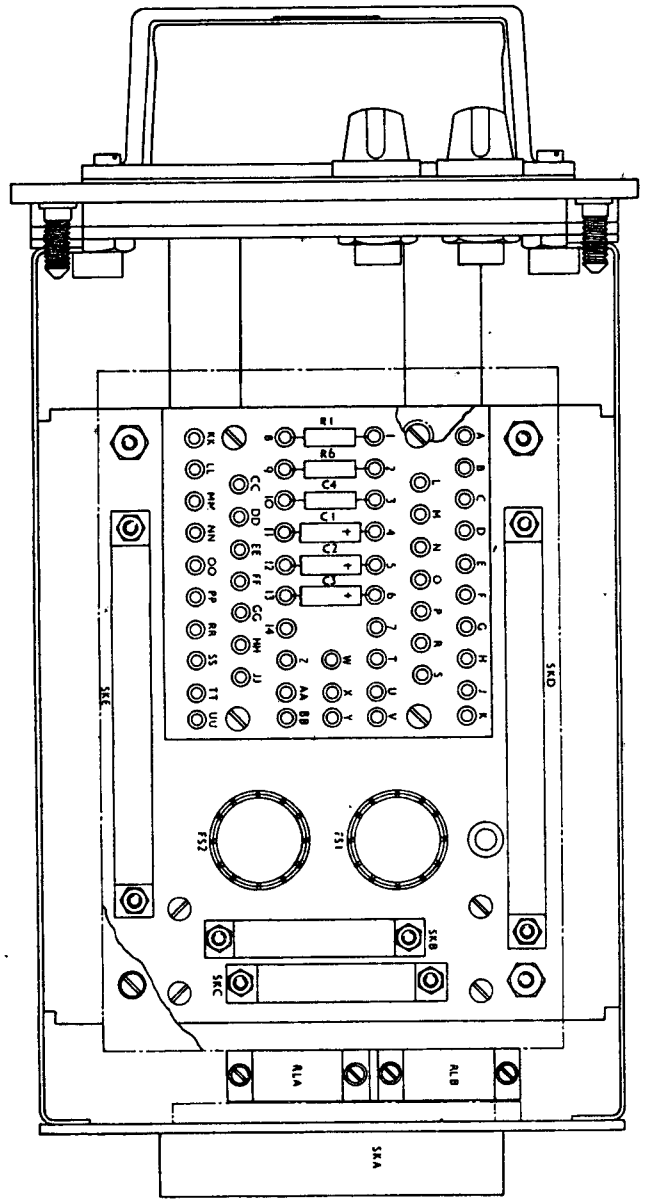

UNDERSIDE VIEW

NOTE-

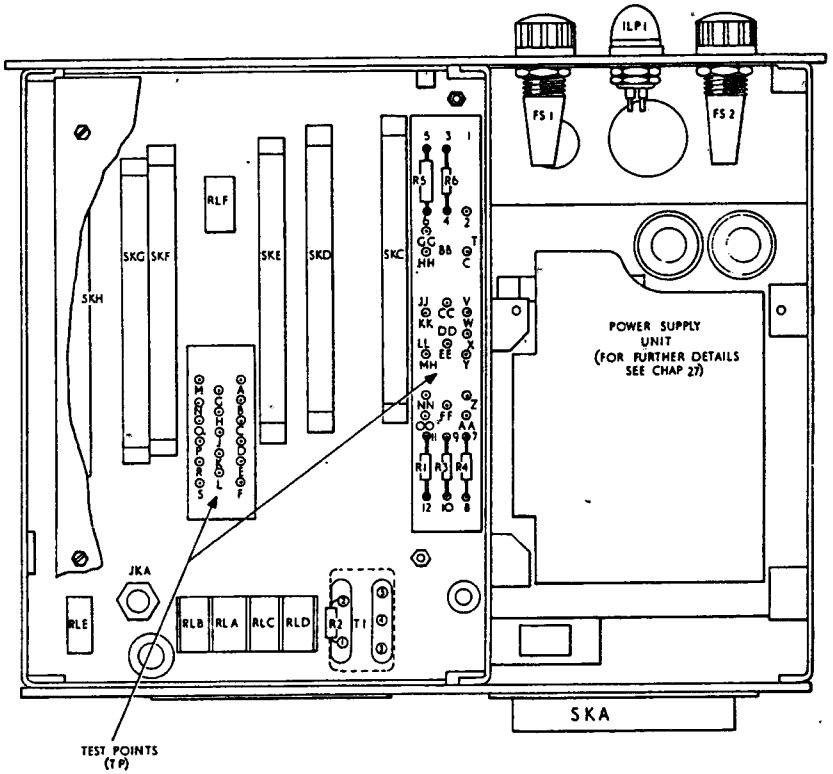
THE FOLLOWING SUB-ASSEMBLIES ARE USED-

| | | |
|---|---|---|
| SKB | GATE ELECTRONIC COUNTER | (CHAP 24) |
| SKC | SWITCH UNIT, ERROR LAMPS | (CHAP 26) |
| SKD, SKE | COUNTER ELECTRONIC DIGITAL | (CHAP 25) |

# DIGITAL READOUT UNIT
## COMPONENT LAYOUT



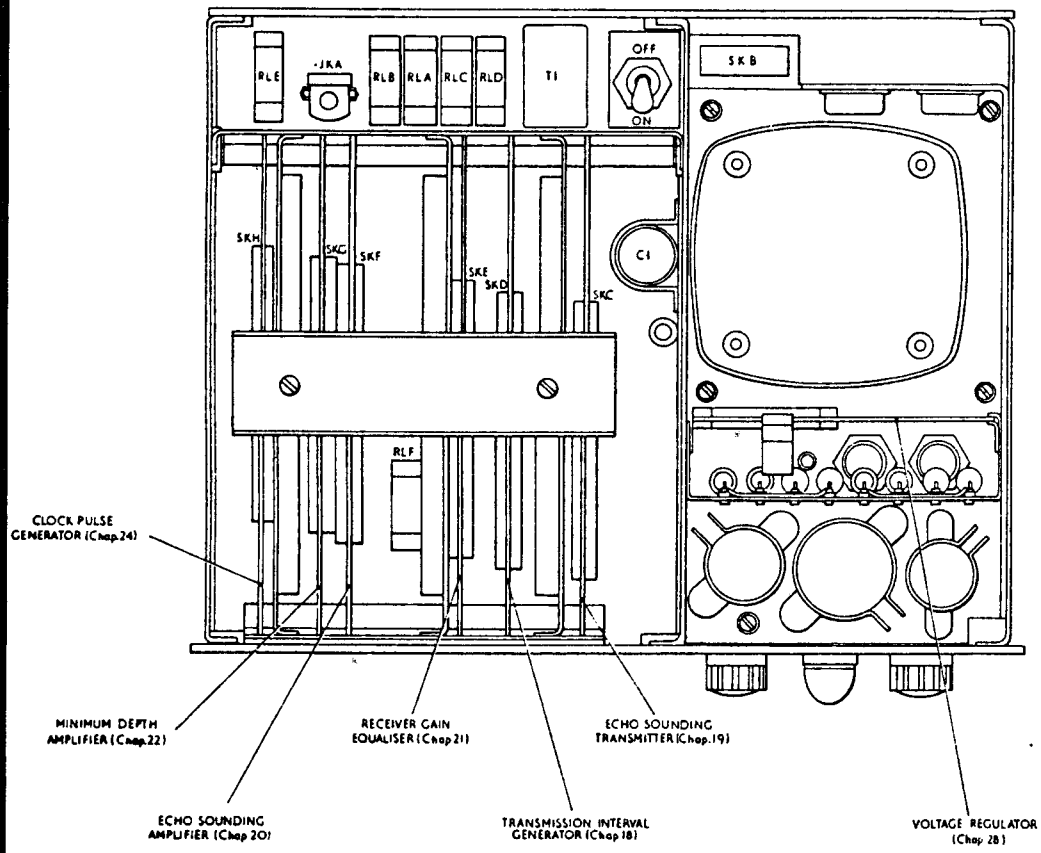

DIGITAL READOUT UNIT, DEPTH
UNDERSIDE VIEW

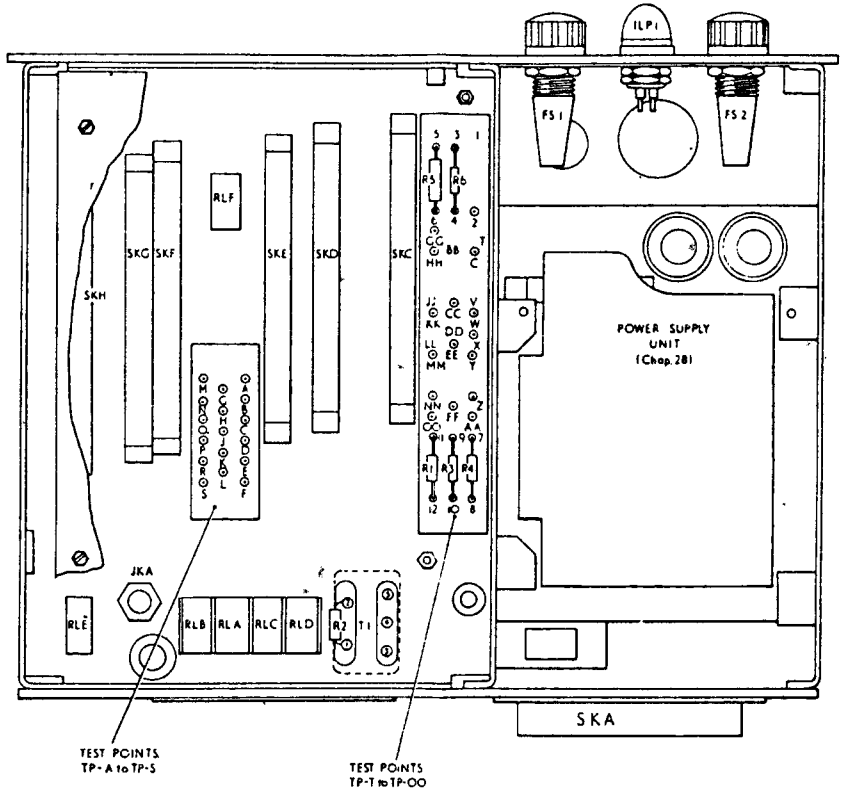



RECEIVER TRANSMITTER
UNDERSIDE VIEW

## BRIDGE UNIT
COMPONENT LAYOUT

FIG. 2.2



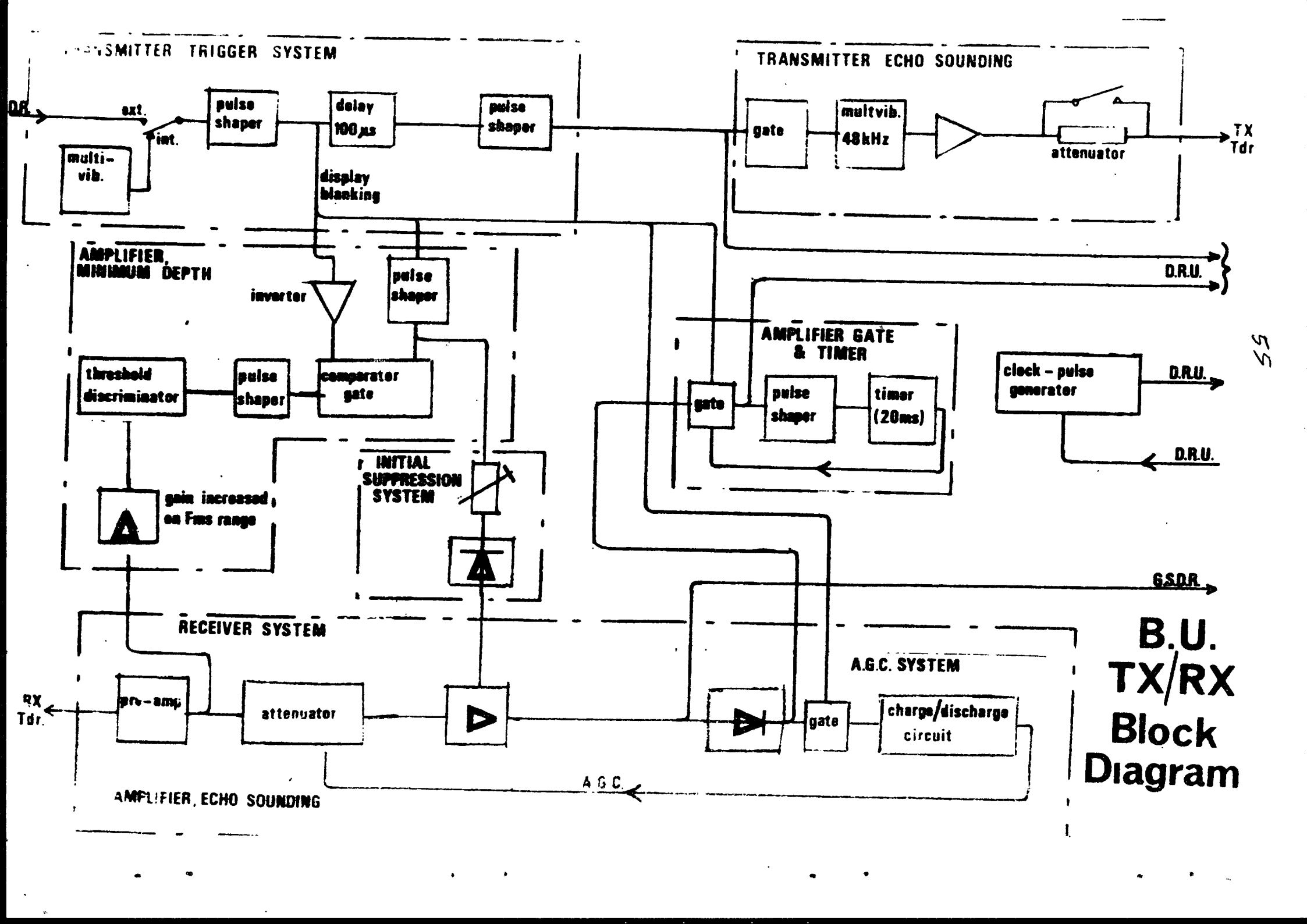




UNDERSIDE VIEW

# RECEIVER/TRANSMITTER
## COMPONENT LAYOUT

FIG.6A.2.1

45


TRANSMITTER TRIGGER SYSTEM
TRANSMITTER ECHO SOUNDING
D.R.
ext.
int.
multi-vib.
pulse shaper
delay 100 µs
pulse shaper
display blanking
gate
multvib. 48kHz
attenuator
TX Tdr
AMPLIFIER, MINIMUM DEPTH
inverter
pulse shaper
D.R.U.
AMPLIFIER GATE & TIMER
threshold discriminator
pulse shaper
comperator gate
gate
pulse shaper
timer (20ms)
clock - pulse generater
D.R.U.
D.R.U.
INITIAL SUPPRESSION SYSTEM
gain increased on 5ms range
G.S.D.R.
RECEIVER SYSTEM
A.G.C. SYSTEM
RX Tdr.
pre-amp
attenuator
gate
charge/discharge circuit
A.G.C.
AMPLIFIER, ECHO SOUNDING
B.U. TX/RX Block Diagram

## GENERAL PURPOSE ECHO SOUNDER TYPE 778

### SUBMARINE VARIANT (Fig. 1)

The General Purpose Echo Sounder Type 778 was designed and developed by Kelvin Hughes to replace the Type 765 Echo Sounder. It is now also being used to supercede Echo Sounders Type 773 and 776 (excluding the 776 ice detection capability).

The equipment consists of two interconnected Echo Sounding sets capable of independant operation. They are:

1. A Medium/Deep Navigation set comprising a General Service Depth Recorder (GSDR) and a Medium/Deep Transducer. Together they produce a permanent analogue record of depth to a maximum of 4,500 fathoms.

2. A Command instrument termed the Bridge Unit (BU) comprising a VCS type display, receiver/transmitter and a shallow sounding transducer. They produce a digital readout of depth to a maximum of 99 fathoms, and if required an analogue record can also be produced on the GSDR of the Medium/Deep equipment.

### GENERAL SERVICE DEPTH RECORDER (Fig.1 )

This is a fully transistorised, repair by replacement unit similar in size to the 773 Echo Sounder recorder.

The trace display is a true profile picture in that the transmission mark is at the top of the trace, and the echo is at the bottom. The recording paper, which is 8 inches wide and of the dry variety, is moved from right to left across the front of the recorder. The stylus which is mounted on a pulley driven belt, moves from the top to the bottom of the chart.

The depth scales and phases for the recorder as shown in Table 1.

| Scale Phase | 225 fms | 450 | 4500 | Phase Marker Pos. |
|---|---|---|---|---|
| 1 | 0-60 | 0-120 | 0-1200 | Tx Mark |
| 2 | 45-105 | 90-210 | 900-2100 | Below 1st Depth Mark |
| 3 | 90-150 | 180-300 | 1800-3000 | Below 2nd Depth Mark |
| 4 | 135-195 | 270-390 | 2700-3900 | Below 3rd Depth Mark |
| 5 | 180-225 | 360-450 | 3600-4500 | Tx Mark near trace bottom |

Depth Marker lines are displayed at 5, 10 and 100 ftms in the respective ranges to assist in depth measurement.

General Purpose Echo Sounder Type 778 - (contd)

The trace can be adjusted for two different speeds of sound in water ie. 4800 ft/sec and 4920 ft/sec. These speeds are indicated on the trace by a dotted line above the Tx mark when switched to 4800 ft/sec. The space is blank when in 4920 ft/sec.

## TECHNICAL DESCRIPTION - TRANSMISSION (Fig. 3)

Two crystal oscillators produce frequencies of 20.992 KHz and 20.48 KHz. These frequencies are used to represent the two speeds of sound in water. The required frequency is selected by the sound velocity switch and fed into a divide by 256 circuit. This circuit output is used to produce the 5 fathom depth markers. The output can be further divided to produce the 10 fathom markers. These marker pulses are fed away to:

1. The depth marker generator (external).

2. Divide by 10 circuit (internal) which produces the 100 fathom marks.

3. And via the circuit below as a trigger initiation for transmission (Fig. 4).

The selected frequency is also fed directly to the Motor Drive Amplifier w where it is fed into 3 integrator circuits, the outputs of which feed 3 J-K bistables connected by feedback. These produce a 3 phase square wave output which drives a synchronous motor connected to the stylus drive. When the 4500 fathom range is selected two of the three phases are transposed to reverse the motor rotation which then drives the stylus assembly, through gearing at a slower speed. The motor belt also drives a magnetic shutter which is notched to allow the contacts of a reed switch to be closed by the action of a permanent magnet once per cycle of the shutter. The switch operates 5 times per revolution of the belt.

The re-opening of the reed switch contacts, which is co-incident with the trailing edge of the shutter aperture, provides a triggering signal. This signal is summed with the signal produced by an encoder which contains 5 earthed contacts which can be individually selected by the phase switch. Each contact is open circuit during a different arc of rotation of the encoder to provide a "window" for each of the 5 operations of the reed switch. The summed signal provides the trigger signal to initiate the transmission.

The trigger signal is fed to the Depth Marker Generator where it switches on a multivibrator. The step output is passed to the Gating circuit of the Echo Sounding Transmitter and allows the 10 KHz transmission pulse to pass to the transducer via the Power Output switch. The pulse length of the transmission pulse is controlled by the Gating Circuit.

General Purpose Echo Sounder Type 778 - (contd)

## RECEPTION

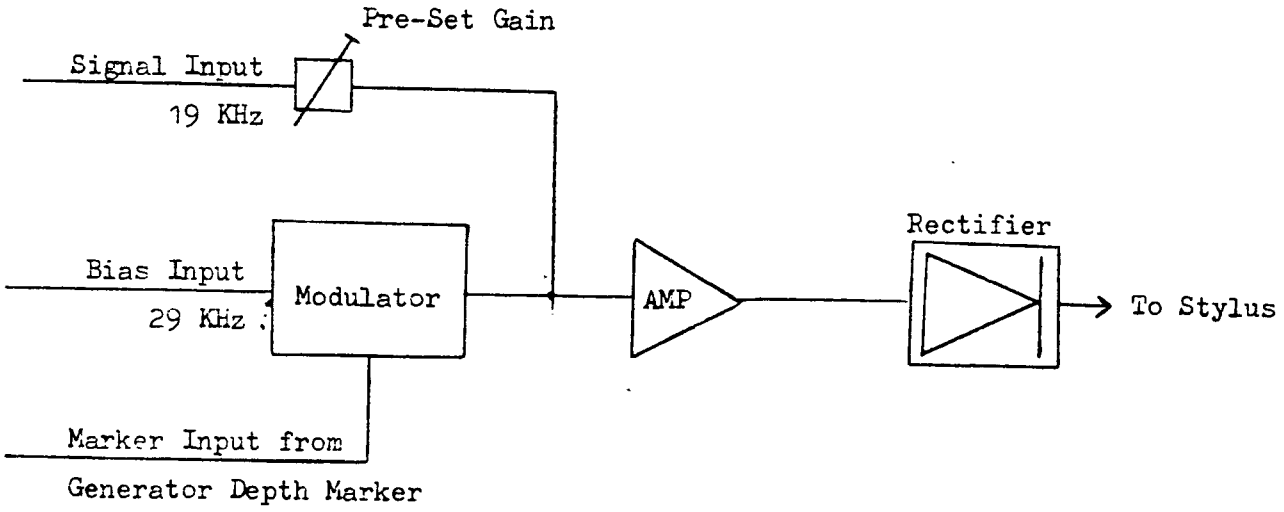
The transmitted signal is also passed to the Initial Reverberation Suppressor where it is rectified and passed to an Emitter Folower. The resultant negative voltage pulse, the duration of which is equal to the transmission period, is passed to the Receiver Pre-Amplifier. The Pre-Amplifier contains the transmit/receive switch which short circuits its tuned amplifier during the transmission pulse, thus protecting the receiver circuits. Also included in this circuit is a system of Time Varying Gain whereby the suppression pulse is fed to the Tuned Amp to reduce its gain to a minimum during the transmission period. During reception the gain rises exponentially thus giving greater amplification to echos from greater depths.

When an echo is received it passes through the tuned amplifier to the Receiver Gain Control in the Echo Sounding Amplifier. Here it is filtered through a 2 KHz bandwidth filter when in the 225 fathom range (250 Hz bandwidth filter is used in the other two ranges). The signal is amplified by approximately 90 db's and passed to the:

1. Echo signal modulator.

2. Audio amplifier.

The signal passed to the Echo Sounder Modulator is processed as shown below:



General Purpose Echo Sounder Type 778 - (contd)

The signal input (19 KHz) is produced by hetrodyning the Transmission Signal with 29 KHz in the Echo Sounder Modulator.

An audio output is produced by down hetrodyning the 10 KHz echo in the audio amplifier and feeding the 1 KHz note to the loudspeaker and the headphone socket via a volume control.

## THE BRIDGE UNIT (Figs. 5 & 6)

This unit comprises the receiver/Transmitter and the digital readout unit. The system is designed to provide a digital indication of depth from 6 feet to 99 fathoms. It can be operated independantly of the GSDR without interference, or the GSDR may be switched to record the Bridge Unit echo signals to a depth of 225 fathoms. The equipment operates for a set speed of sound in water of 4920 feet/sec, at a frequency of 48 KHz.

## TECHNICAL DESCRIPTION - TRANSMISSION (Fig. 7)

A trigger input, which is produced in the receiver/transmitter, is shaped to produce a display blanking pulse which is used to:

1. Trigger the transmitter.
2. Provide initial reverberation suppression.
3. Provide initial timing for:
   a. Minimum depth system.
   b. Time gate.
   c. AGC system.

To ensure that the receiver is inhibited before a transmission can occur, the blanking pulse is delayed by 100 $\mu$ sec, before it is fed to the transmitter, and also the digital readout unit, as a start pulse. The transmission is produced by gating a 48 KHz oscillator 'ON' for either 200 $\mu$ sec (feet range) or 500 $\mu$ sec (fathom range).

## RECEPTION

A received echo signal is fed to the Echo Sounding Amplifier where it is amplified and outputs fed to:

1. The receiver gain equaliser.
2. The minimum depth amplifier.
3. The amplitude gate.
4. The GSDR.

General Purpose Echo Sounder Type 778 - (contd)

The echo signal is passed to the receiver gain equaliser where, if it is of sufficient amplitude, it triggers on AGC voltage which is immediately fed back to the echo sounding amplifier to reduce the gain by 6 db's. When the echo falls below its trigger level, the AGC voltage falls and allows a 3 db increase in receiver gain by the time the next echo pulse is due.

The echo signal is also fed to the minimum depth amplifier. If the depth is less than 6 ft circules are displayed on the digital display. If the depth is greater than 6 ft this part of the circuit is bypassed. The signal then passes to the amplitude gate where it is gated with the display blanking pulse to prevent a signal being passed during the transmission period. Provided the echo is of sufficient amplitude it will 'fire' a monostable which will feed the digital readout unit with a 'stop' pulse.

This stop pulse is fed back to the gate to prevent the receipt of multiple echos.

The blanking signal (start pulse), which was initially fed away to the Clock Pulse Generator, opens a gate at the instant of transmission. This gate opening allows pulses from a 2.4 KHz clock generator to pass to the counter. Once the echo is received a stop is fed to the gate which shuts, stopping the counter. Thus the gate is only open for the time period between the transmission and the echo. The pulses from the Clock Pulse Generator are 'counted' in the digital counter and displayed on a 2 digit screen. The third digit is used to display either FT or FMS depending on the range selected.

If the depth is below 99 ft or fathoms the Clock Pulse Generator will 'overcount' and pass a signal to the overcount circuit and cause the display to show crosses over the digits as an indication of too great a depth for the equipment.

## USE OF THE GSDR AND BU COMBINED

As well as using both sets indpendantly, they can be combined to form a shallow echo sounding unit giving both digital and analogue records. In order to do this the GSDR is siwtched to either FM or FMS(BU) and the depth scale to 225 fathoms. This will automatically put supplies onto the Bridge Unit. The GSDR will print the echos automatically in fathoms regardless of the scale shown on the digital readout unit. OR FEET

The transmission is initiated from the GSDR and, therefore, the transmission switch on the GSDR must be to ON. This allows the pulsed signal from the transmitter trigger in the GSDR to be sent to the transmission interval generator in the BU and the signal flow is then as for normal BU operation.

The received echo is passed from the echo sounding amplifier to the echo sounding modulator in the GSDR and then to the print system. To produce the 19 KHz signal in the print system the 48 KHz pulse is mixed with 29 KHz signal already present in the stylus drive amplifier.

General Purpose Echo Sounder Type 778 - (contd)

## FITTING POLICY MAINTENANCE AND REPAIR

The present Fleet policy is to fit all Submarines, except SSBNs, with the equipment.

The maintenance of the set is repair by replacement and the documentation has been FIM'med to make maintenance easier. As far as can be assessed the set has proved very reliable during trials, but from information received has caused some problems during initial dockyard fitting.

## SONAR TYPE 778 TRANSDUCERS

This is a new Echo-Sounder being introduced into the Navy, and it conbines the capabilities of both 773 and 776, together in one set. Predictably, therefore, it has two transducers one for Deep Work and one for Shallow.

### DEEP TRANSDUCER (0633/5845 - 99 - 920 - 3377)

This is a direct replacement of the 773 transducer (0633/520 - 3377). It comprises of a matrix of piezo-electric elements which are housed in an Aluminium-Silicon-Bronze forging. Each element consists of five Barium Titanate rings which are mounted between an Aluminium-Silicon-Bronze head and a countermass. A centre bolt keeps the stack compressed even at the maximum amplitude of vibration.

The transducer is mounted on, and insulated from, brackets inside a free-flood space. Sufficient cable is wound on a drum mounted on top of the transducer so that it may be taken through the bottom of the Submarine and up to the deck for servicing.

### TRANSDUCER TESTING

Tested at contacts TSA27 and 28 on the GSDR. Continuity resistance between cores 25 $\pm$ 5 . Insulation resistance between core and earth should be greater than 20 Mn.

### TRANSDUCER REMOVAL AND REPLACEMENT

Reference BR 2800(3) Chapt 28 Part 5 Sect 3 (Echo Sounder Type 778 Handbook).

### SHALLOW TRANSDUCER (0633/5845 - 99 - 920 - 6881)

The shallow transducer, which is used in conjunction with the Bridge Unit, comprises a GRP housing containing two Magneto-Striction elements. One is used for transmission and the other for reception. Each element embodies a pair of reflector plates spaced at $\frac{1}{4}$ wave length to cancel out back response. Tuning capacitors are connected in parallel with each element at the tuning box.

The transducer is bolted to a seating ring inside a free flood tank which is vented to a free flood space. Sufficient cable is wound on a drum mounted on the back of the transducer so that it can be brought up to the casing for maintenance.

### TRANSDUCER TESTING

Transmitter: Disconnect Red (L1) and Blue (L2) leads from the tuning box. Using a CT 471 between wires check that the reading is 5n Max. Connected between one wire and earth check that the insulation resistance is not less than 40 Mn.

Receiver: Disconnect the Black or Green (L3) and the Yellow or White (L4) leads from the tuning box. Using a CT 472 between wires check that the reading is 1.5 n Max. Connected between one wire and earth check that the insulation resistance is not less than 40 Mn.

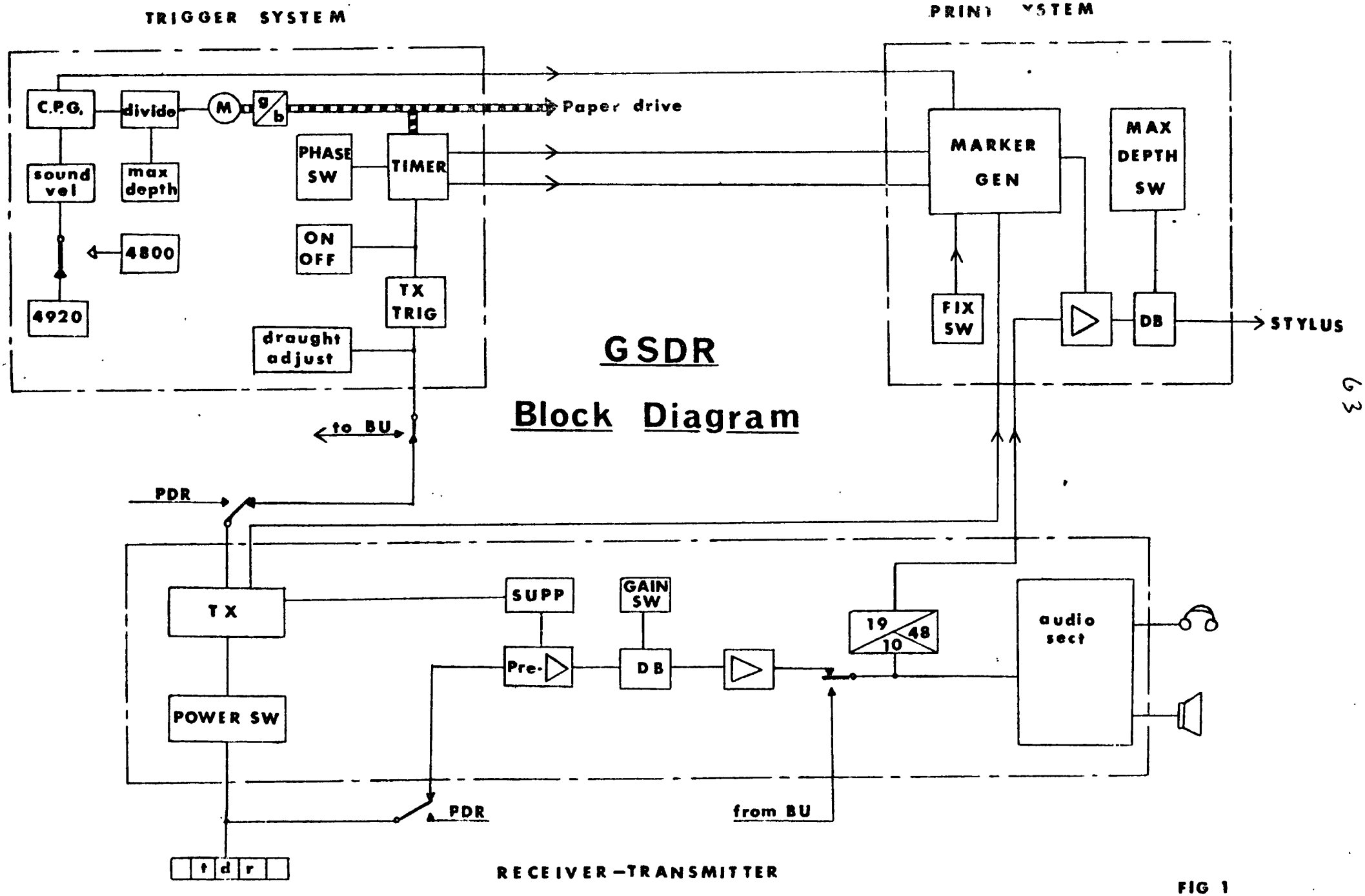

TRIGGER SYSTEM
PRINT SYSTEM
C.P.G.
divide
M
g/b
Paper drive
sound vel
max depth
PHASE SW
TIMER
4800
4920
ON OFF
TX TRIG
draught adjust
MARKER GEN
MAX DEPTH SW
FIX SW
DB
STYLUS
GSDR
Block Diagram
to BU
PDR
TX
SUPP
GAIN SW
Pre-
DB
19
48
10
audio sect
POWER SW
PDR
from BU
t
d
r
RECEIVER–TRANSMITTER

FIG 1

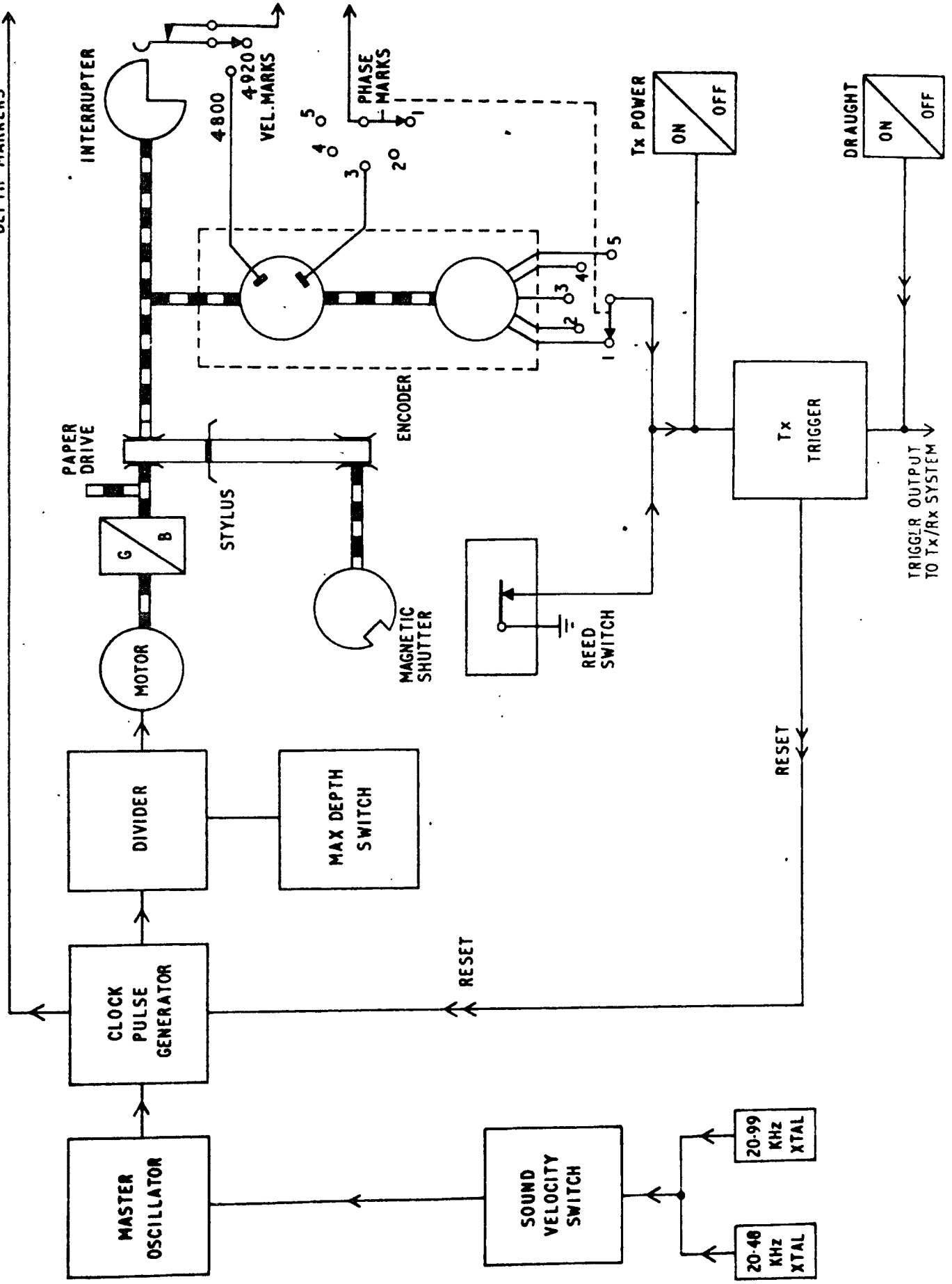

DEPTH MARKERS
INTERRUPTER
4800
4920
VEL. MARKS
PHASE MARKS
5
4
3
2
1
Tx POWER
ON
OFF
DRAUGHT
ON
OFF
ENCODER
PAPER DRIVE
STYLUS
G
B
MOTOR
MAGNETIC SHUTTER
REED SWITCH
Tx TRIGGER
TRIGGER OUTPUT TO Tx/Rx SYSTEM
RESET
DIVIDER
MAX DEPTH SWITCH
CLOCK PULSE GENERATOR
RESET
MASTER OSCILLATOR
SOUND VELOCITY SWITCH
20-99 KHz XTAL
20-40 KHz XTAL

FIG 3

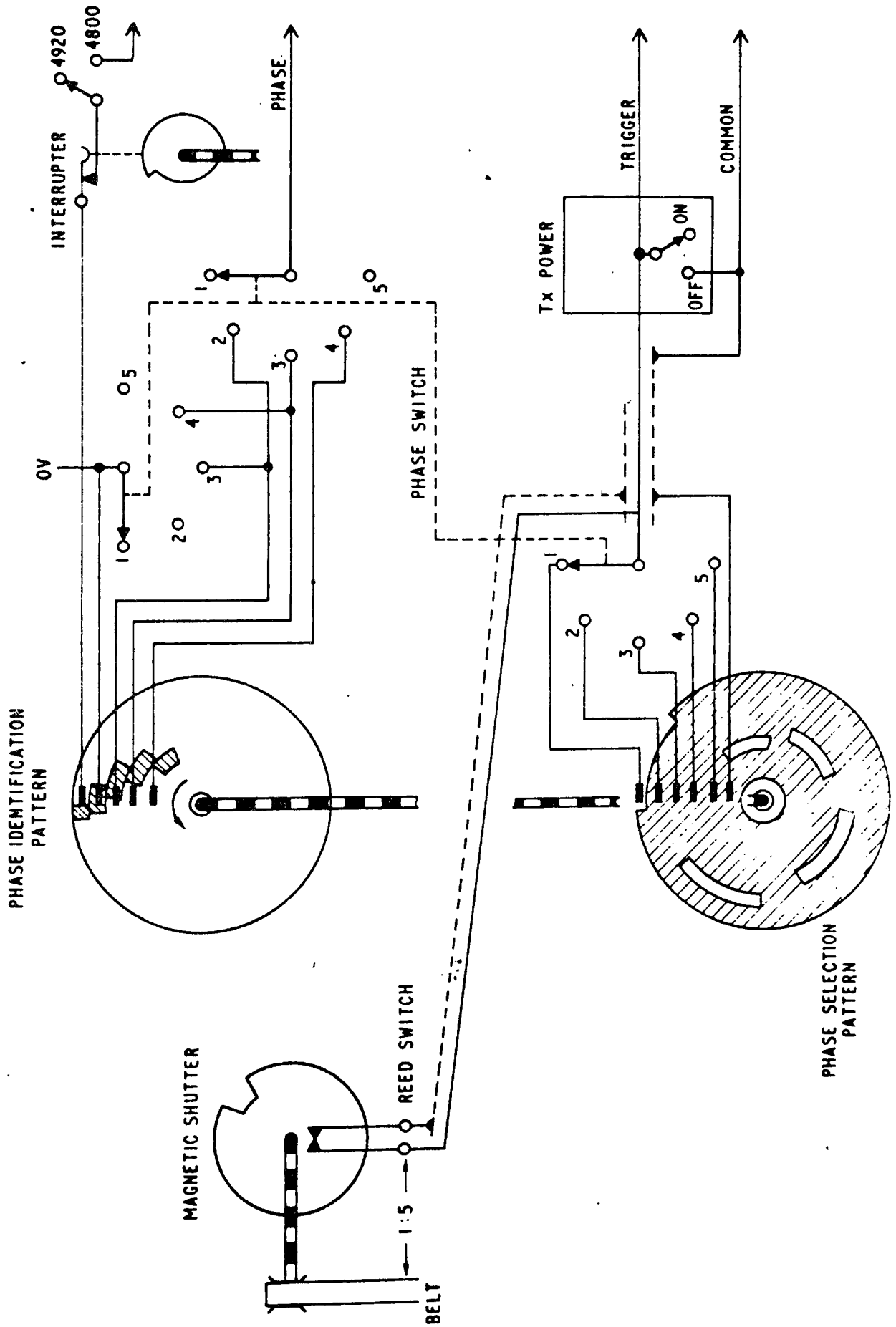

4920
4800
INTERRUPTER
PHASE
TRIGGER
COMMON
Tx POWER
ON
OFF
0V
PHASE SWITCH
PHASE IDENTIFICATION PATTERN
PHASE SELECTION PATTERN
MAGNETIC SHUTTER
REED SWITCH
1:5
BELT

FIG 4

# 778 BRIDGE UNIT TRANSMITTER-RECEIVER UNIT

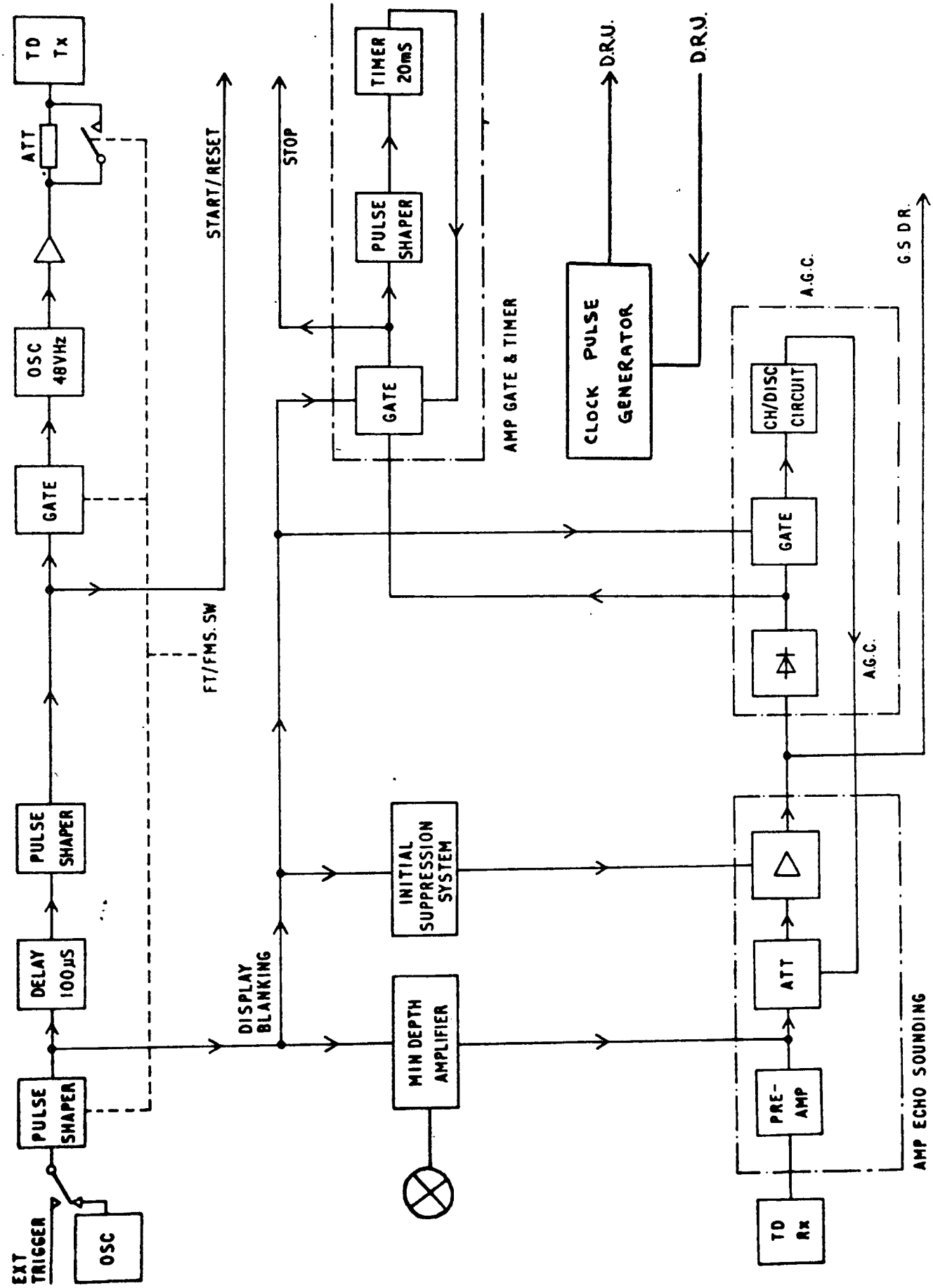



FIG 5

# 778 BRIDGE UNIT – DIGITAL READOUT UNIT

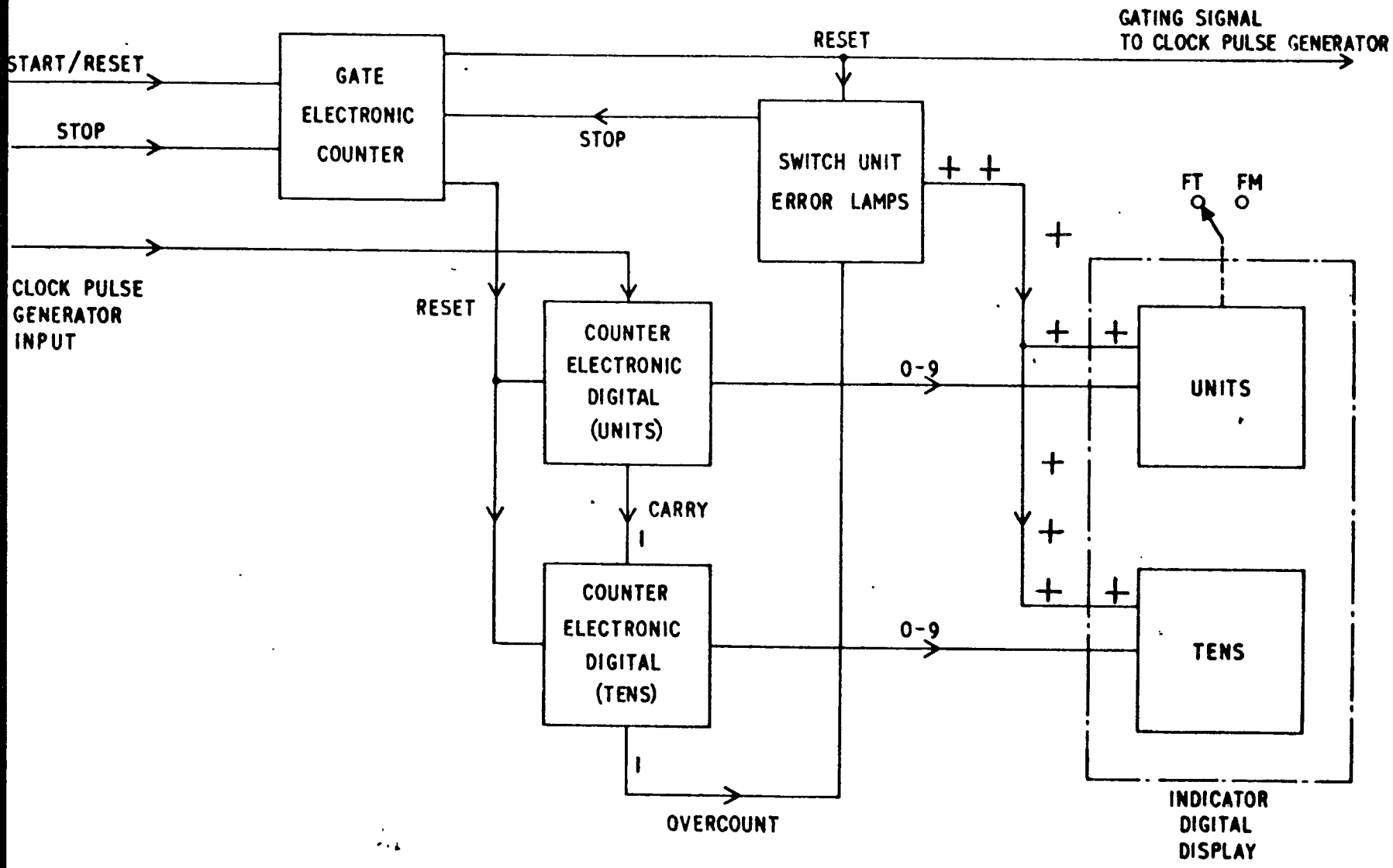
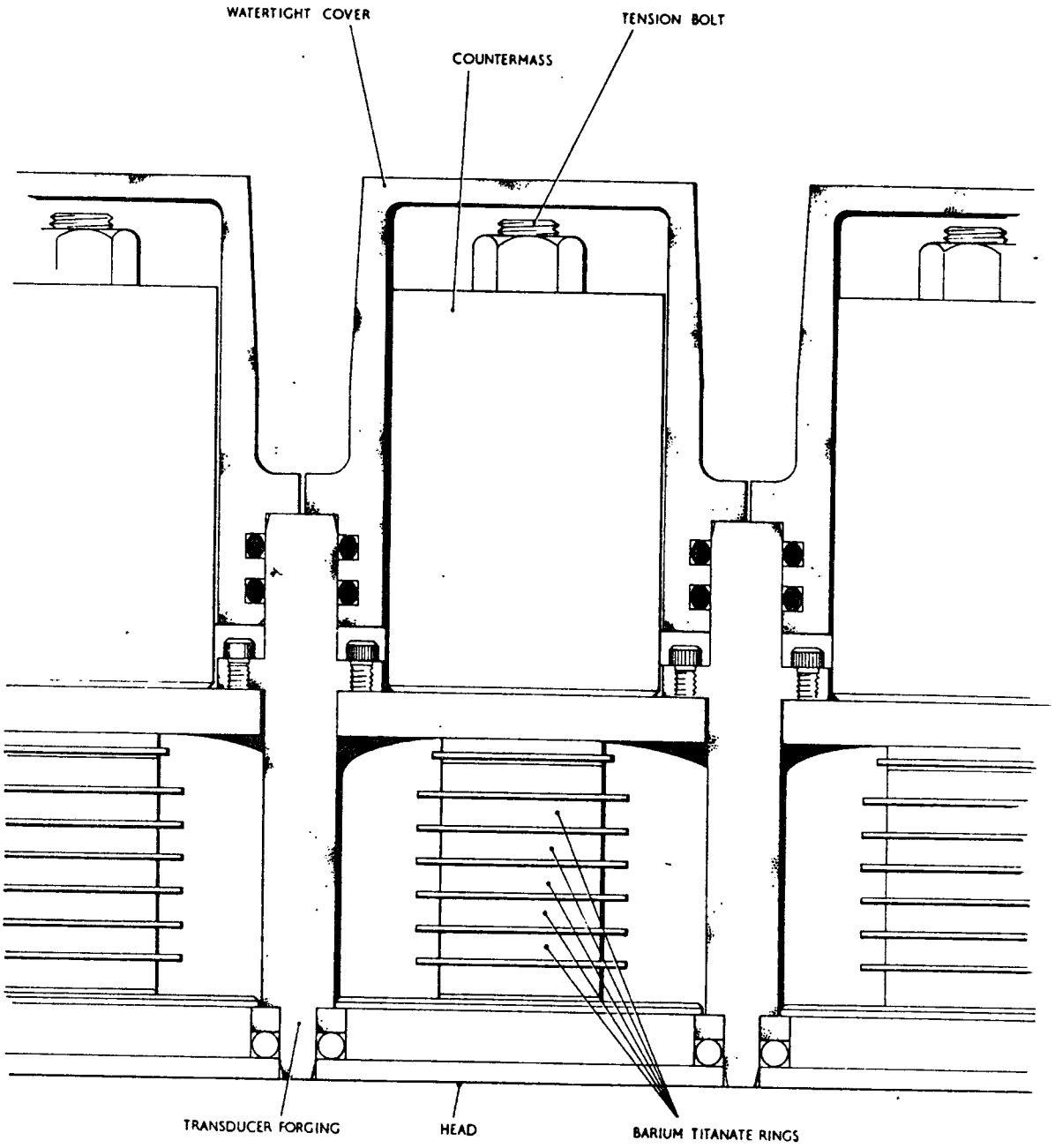
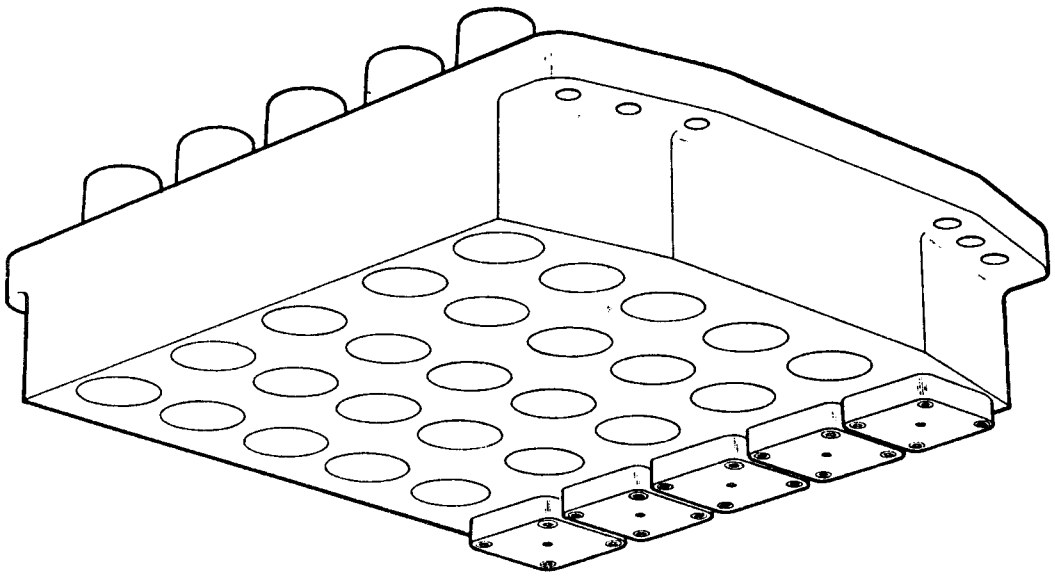



FIG 6




# TRANSDUCER ELEMENT
DIAGRAMMATIC

FIG. 5.29.1



TRANSDUCER 5845-99-520-3377

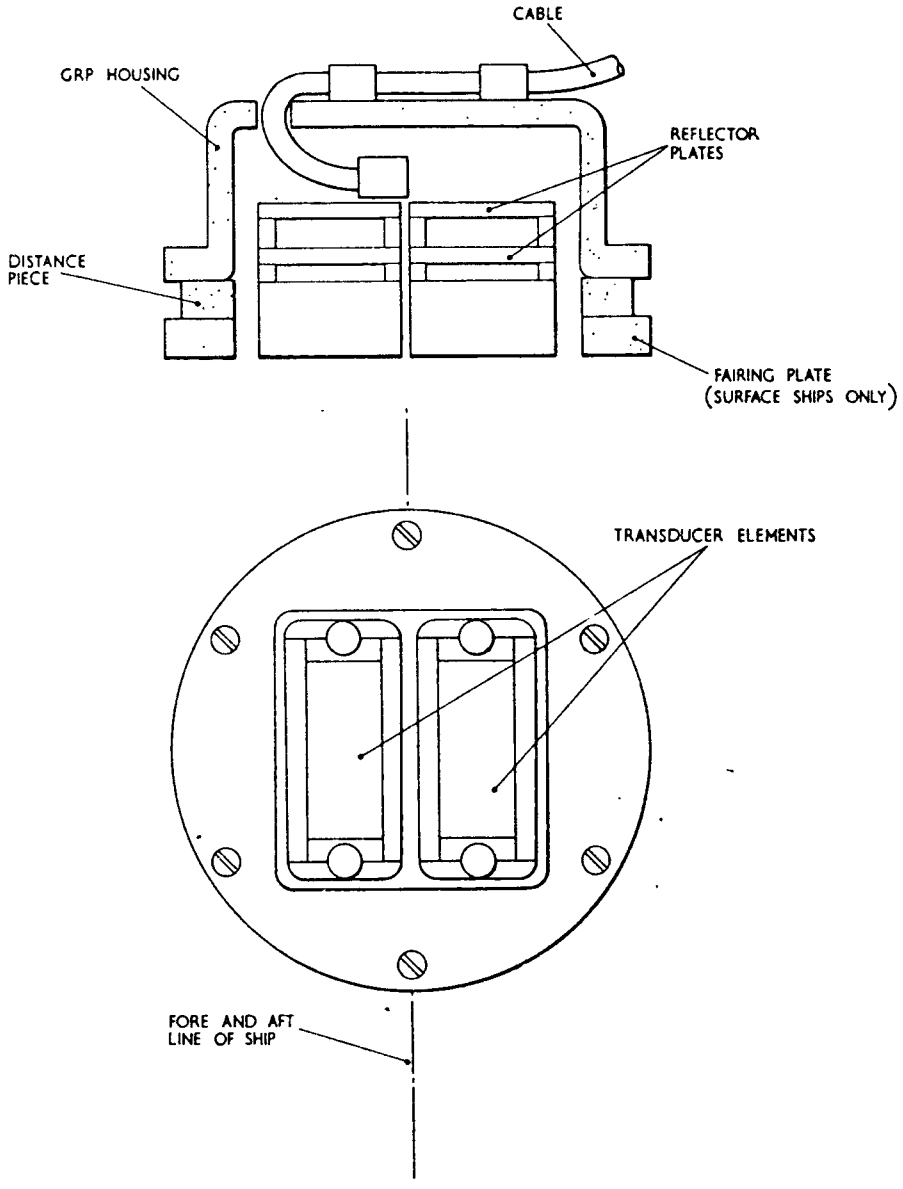



FIG.5.30.1 GENERAL VIEW OF TRANSDUCER

# SUBMARINE EXPENDABLE BATHYTHERMOGRAPH

GENERAL INFORMATION

The Submarine Bathythermograph or SSXBT measures the temperature profile down to 2500 ft. in 180 seconds with little effect on the submarines manuvering.

The set consists of :(1) Expendable Bathythermograph devices.
(2) Breech door and cable feed thru mounted on the aft SSE.
(3) Connector box for wire connection.
(4) Recorder.
(5) Dummy load for system test.

REFERENCE DATA :

| | |
|---|---|
| Temperature sensing range | 28°F to 96°F, -2°C to 35°C |
| Temperature accuracy | ± 0.4°F, ± 0.2°C |
| Depth range | 0 to 2500 feet |
| Depth accuracy | ± 2% or 15 Feet whichever is greater |
| Recording time | 178 secs for 2500 feet drop |
| Launching depth | 1000 Ft maximum |
| Power requirements | 115 V 60 Hz Single phase |

DESCRIPTION OF UNITS

PROBE

The SSXBT probe is contained in a bouyant float assembly. The float also contains the lifting body. When the SSXBT is launched, the lifting body is separated from the float assembly, and tethered to the submarine by a twin conductor steel wire. The lifting body goes behind the SSE, on the twim cable. The float rises to the surface when the absence of pressure releases the probe for its trip to the bottom. The probe contains a temperature sensitive device and the temperature is relayed to the recorder. The probe is weighted and stabilized to assure accurate velocity profile. When the probe is released, a sea water return circuit triggers the recorder measurement. The recorder plots temperature on the horizontal axis of the vertically driven paper. Since the rate of desent is known, depth can be read directly from the vertical scale on the chart paper. After passing 2500 feet, the probe exhausts its wire and sinks to the bottom.

BREECH DOOR AND CABLE FEED THRU

Insures watertight integrity, yet passes a two conductor wire into the submarine. Tether wire is then connected via the connector box to thr Recorder. Cable feed-thru consists of a small arifue and gland nut assembly to tightly seal a rubber grommet around the tether wire. A wire grip secures the tether wire to the SSE and a shear to sever the wire on completion of the measurement.

CONNECTOR BOX

Ensures a reliable electrical connection to the SSXBT tether wire and provides visual indication of system status. With lever in the reload position, the tether wire can be inseted thru the bottom and viewed through the front. With the lever to the LAUNCH position polarity correct connection is made to the tether wire. Connector Box status lamps indicate system readiness to RELOAD or LAUNCH SSXBT.

OPERATION

The SSXBT probe is fired from the aft SSE. The lifting body which is connected to the Submarine by an insulated, two conductor, steel wire, separates from the float assembly. The lifting body lies behind the SSE. It allows the fine wire cable to peel off a spool to counteract the submarines forward motion, and allows the float assembly to rise independantly of the effects of the submarines movement. The float assembly also holds a spool of the fine wire which dereels as required by the assent rate of the float assembly as it rises to the surface. When the float assembly reaches the surface atmospheric pressure acuates a pressure release mechanism. This releases the probe for its desent. On release a seawater return circuit is completed which triggers the recorder movement. The varing temperature of the water as the probe sinks causes the resistance of the thermister to vary. By using the seawater as a return circuit and the fine wire connected to the recorder, the temperature profile is ploted on the recorder.

THE MAJOR UNITS ARE:

(1) STATUS INDICATOR LAMPS: Status indicator lamps are mounted to the left and right ends of the temperature scale. They indicate system RELOAD and LAUNCH.
(2) TEST PANEL: Test panel is located at the right hand end of the temperature scale. The 94° - 30° permits calibration checks in conjunction with the TEST DEVICE.
(3) TRIGGER DELAY CIRCIUT: During the LAUNCH mode, the trigger delay prevents the recorder from false triggering due to SSE flooding, or other conditions. In the MEASURE mode, the chart drive is delayed 1.3 sec. to permit probe exit, and assure accurate depth scale.
(4) CHART DRIVE: Powered by a timing motor, the chart drive precisely controls chart speed independant of voltage or frequency variations. 12" of paper is used for each XBT.
(5) BRIDGE TRIGGER LOGIC AND POWER SUPPLY: The bridge circuit monitors thermister resistance and directs a temperature dependant signal to temperature servo. It is supplied by a controlled current source, in order to minimize the effect of sea-water and wire resistance. The trigger logic sequences recorder through 4 modes.
They are: (1) LAUNCH MODE
(2) CHECK/RUN MODE
(3) MEASURE MODE
(4) RELOAD MODE

The power supply produces D.C. voltages for bridge, trigger logic, chart drive and status indicators.
(6) TEMPERATURE SERVO: The temperature servo consists of a servo amplifier, servo motor and a servo potentiometer. The amplifier boosts low level bridge signals and drives a two phase motor to horizontally position the chart paper stylus. Chart paper is 7" wide and is equal to a temperature range of 28° to 96°. The servo potentiometer monitors the chart stylus position and transmits a position signal back to the bridge circuit, closing the servo feedback loop.
(7) MULTICYCLE CIRCUIT: The multicycle circuit controls the measure mode chart drive duration.

# SONAR ANALYSIS SYSTEM

The Sonar Analysis System selects signals from a number of sonar sources for analysis and recording. The MAJOR units are:

(1) Sonar 2018 Frequency Analyser.
(2) Spectrum Translator Unit (Frelator).
(3) Sonar Analysis Selection Panel (SASP).
(4) Eight Track Tape Recorder.
(5) Omni Directional Hydrophone.
(6) Omni Directional Hydrophone Preamplifier Type C1.

## SONAR ANALYSER TYPE 2018

The Sonar 2018 is a Spectum Analyser primarily intended for analysis of discrete frequency amplitude modulation of noise (termed DEMON) and the low frequency analysis of signals submerged in white noise (termed LOFAR). Bothnarrow and wide band analysis is possible by selection on the unit. The sonar 2018 employs time compression techniques and digital sampling and storing to overcome the inherent real time limitations of signal analysis. To enhance the LOFAR capability, a sperate frequency translator is used- Frelator, enabling the expansion of a selected frequency band on the sonar 2018 for greater resolution. The sonar 2018 consists of a display recorder, Electronics unit and fume Extractor.

## SPECTRUM TRANSLATOR UNIT

The Spectrum Translator Unit (Frelator) is used in conjunction with the Sonar Analyser type 2018 and improves the resolution and the signal to noise ratio of the signal under analysis. The Frelator permits the expansion of finite bandwidth sections of the spectrum under study, allowing the detection of low level periodic signals normally masked on a wide bandwidth display. Facilities on the Frelator allow the selection of a centre frequency and narrow band range, and tuning of the centre frequency allows an expanded frequency domain window to move progressively across the spectrum of the input signal. The Frelator can be bypassed using an external switch, or by selection on the Sonar Analysis Selection panel.

## SONAR ANALYSIS SELECTION PANEL

The SAS panel is a switching unit which allows the operator to select signals from a number of different sources for analysis and recording. The SASP accepts inputs from a number of signal sources and provides a selective output for analysis and recording. These input signals are:

(1) Sonar 2007 Processed Audio.
(2) Sonar 2007 (P) Preamplifier Output.
(3) Sonar 2007 (S) Preamplifier Output.
(4) Sonar AN/BQG Processed Audio.
(5) Sonar 185.
(6) Sonar CSU 3-41 Channels 1 to 4.
(7) Omni Directional Hydrophone.
(8) 1 KHz Oscillator (REFERENCE).

Pre-whitening filters/amplifiers for the following circuits are provided and are fitted in the SAS panel:

(1) Sonar 2007 (P) and (S).
(2) Frelator Interface.

The filters can be switched in or out from the front panel.

TAPE RECORDER - HEWLETT PACKARD MODEL 3968A

The Sonar Analysis System is designed for use with a Four Track Tape Recorder. The Tape Recorder supplied is the Hewlett Packard Model 3968A (D.S.N. 5835-66-105-6651) which is an eight track tape recorder, however only four direct tracks are used.

OMNI-DIRECTIONAL HYDROPHONE

The Omni-Directional Hydrophone is fitted external to the pressure hull under the forward casing to provide a broadband signal for recording and analysis. The sensitivity of the hydrophone is known and thus if an estimate is available of the target range and the gain settings on the SASP are known, the Absolute level of any target signal may be estimated. The hydrophone operates over the frequency range 10 Hz to 40 KHz.

OMNI-DIRECTIONAL HYDROPHONE PREAMPLIFIER TYPE C1

The signal level from the Omni-Directional Hydrophone is boosted using two amplifiers, nominated "C1" and "C2". The "C1" amplifier is fitted at the deckhead Frame 58½ and the "C2" amplifier is located in the Sonar Analysis Selection Panel. The power supply for both these amplifiers is derived from the SAS panel, and a gain control switch is fitted on this panel for remote control of the "C1" amplifier.

PRINTED CIRCUIT BOARDS

There are five printed circuit boards designated PLA, PLB, PLC, PLD and PLE which are housed in the Sonar Analysis Selection Panel in sockets SKTA, SKTB, SKTC, SKTD and SKTE respectively. The P.C.B's are for the following circuits:

PLA Amplifier C2 for Omni-Directional Hydrophone.
PLB 2007 (P) and 2007 (S) Filter Card.
PLC Frelator Interface Filter Card.
PLD Spare.
PLE 1 KHz Oscillator Card.

PLC FRELATOR INTERFACE FILTER CARD

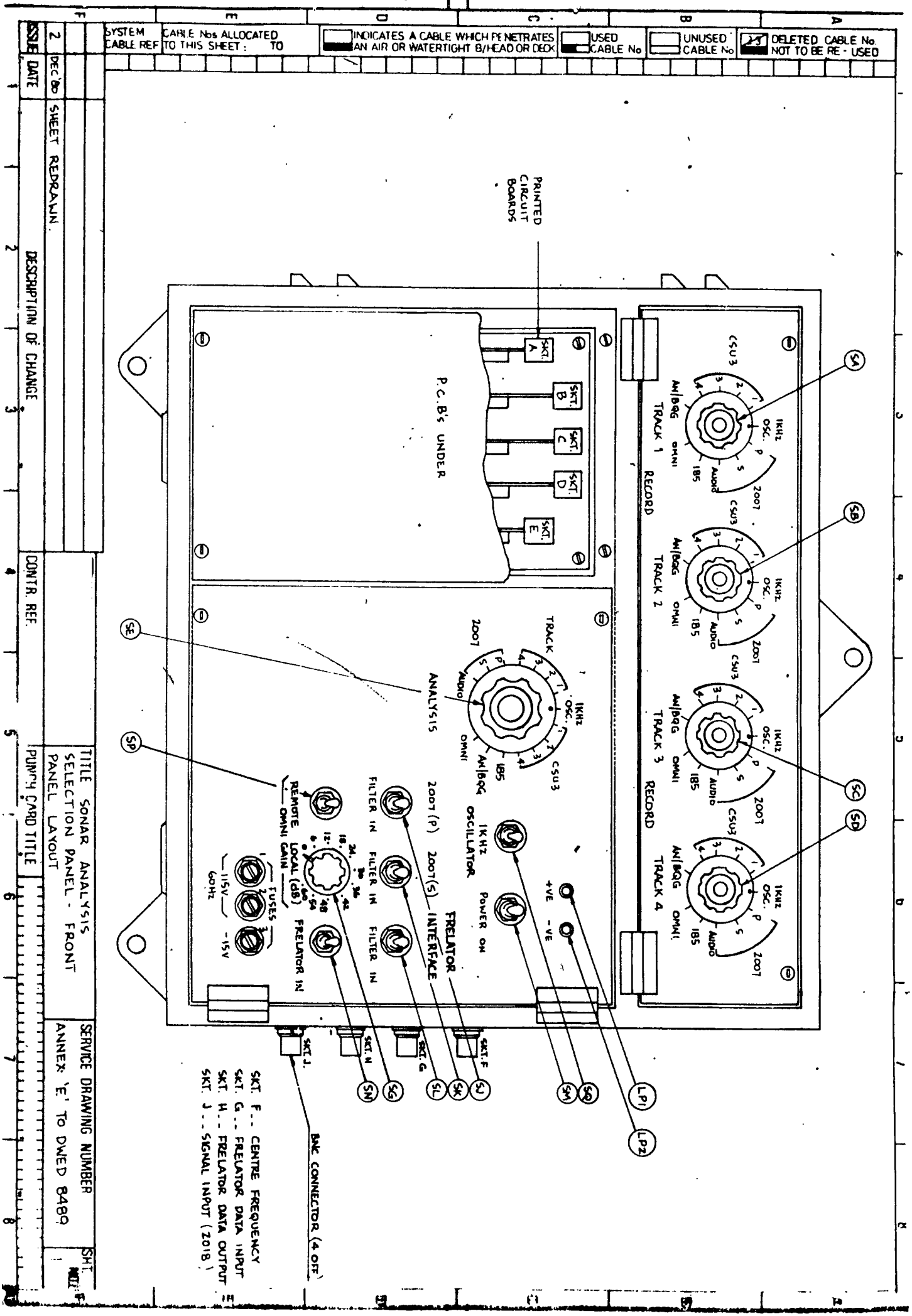
The Frelator interface circuit is designed to limit the dynamic range of the signal which is input to the Frelator. It does this by applying automatic gain control to hold the output at 1V RMS and also by high pass filtering the signal at 300Hz or low pass filtering at 380 Hz depending on the Frelator Centre Frequency. Changeover between the filters occurs at a Frelator frequency of 360 Hz.

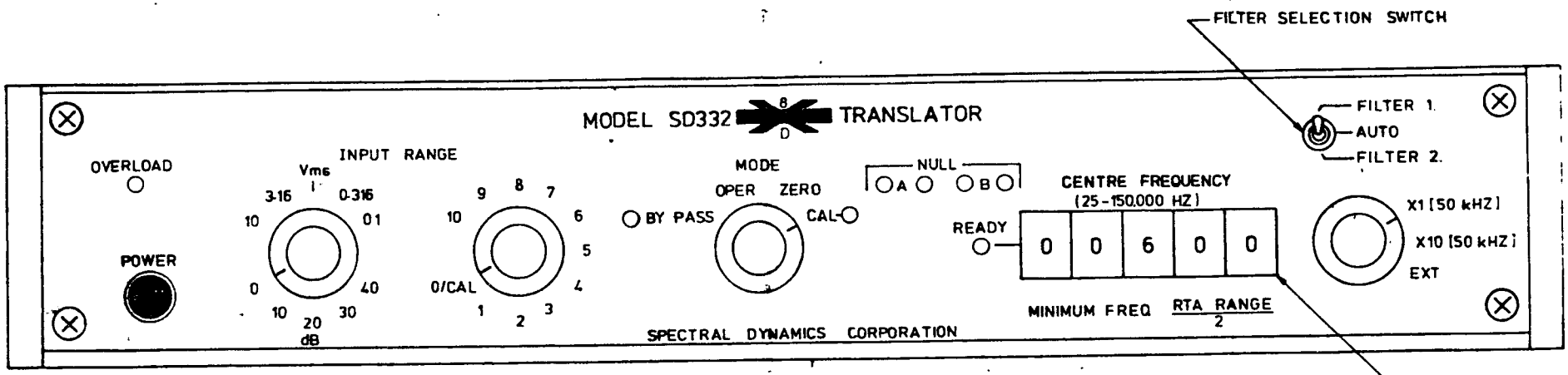
PLE 1KHz OSCILLATOR CARD

The 1 KHz oscillator is used to provide a frequency reference for the 4 track tape recorder and to allow the correct operation of the Frelator to be confirmed. The output frequency is 1 KHz ± 1 Hz and the level may be selected to 100mV or 1V.

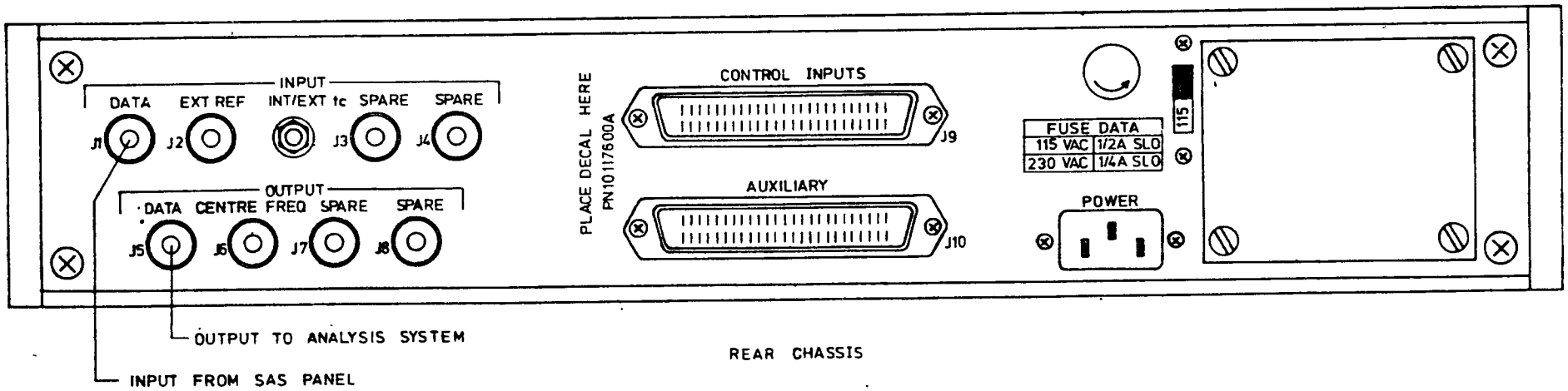
blank

BLANK


SYSTEM CABLE REF
CABLE Nos ALLOCATED TO THIS SHEET: TO
INDICATES A CABLE WHICH PENETRATES AN AIR OR WATERTIGHT B/HEAD OR DECK
USED CABLE No
UNUSED CABLE No
DELETED CABLE No. NOT TO BE RE-USED
ISSUE
DATE
DESCRIPTION OF CHANGE
CONTR. REF.
2 DEC '80 SHEET REDRAWN.
TITLE SONAR ANALYSIS SELECTION PANEL - FRONT
PUNCH CARD TITLE
SERVICE DRAWING NUMBER
ANNEX 'E' TO DWED 8489
PRINTED CIRCUIT BOARDS
P.C.B's UNDER
SKT. A
SKT. B
SKT. C
SKT. D
SKT. E
TRACK 1 RECORD
TRACK 2
TRACK 3 RECORD
TRACK 4
CSU3
AM/BQG
OMNI
185
AUDIO
2007
IKHZ OSC.
ANALYSIS
TRACK
IKHZ OSCILLATOR
POWER ON
+VE
-VE
2007 (P)
2007 (S)
INTERFACE
FRELATOR
FILTER IN
REMOTE
LOCAL (dB)
OMNI GAIN
FRELATOR IN
FUSES
115V 60Hz
-15V
SK
SL
SM
SN
SP
LP1
LP2
SKT. J.
SKT. N
SKT. G
SKT. F
BNC CONNECTOR (4 OFF)
SKT. F.. CENTRE FREQUENCY
SKT. G.. FRELATOR DATA INPUT
SKT. H.. FRELATOR DATA OUTPUT
SKT. J.. SIGNAL INPUT (2018)




FRONT PANEL




REAR CHASSIS

| ISSUE | DATE | DESCRIPTION OF CHANGE | CONTR. REF. |
|---|---|---|---|
| 2 | MAY'81 | ADDED FILTER SELECTION SWITCH. | |
| 1 | JULY'79 | ORIGINAL ISSUE | |

PUNCH CARD TITLE

TITLE SD332 TRANSLATOR - FRELATOR FRONT & REAR PANELS

SERVICE DRAWING NUMBER ANNEX 'C' TO DWED 8489

SHT 1

A3

# ELECTROMAGNETIC LOG

INTRODUCTION:
The Electromagnetic Log measures the ships speed relative to the water, derives Distance Measurement and provides transmission of speed and distance indication as required, either directly or through Re-transmission units, to Navigational and Weapon Systems. The Log is able to produce an accuracy to within 0.1 Knot throughout the speed range, however the staff requirement accuracy is:

| | | |
|---|---|---|
| 0-3 KNOTS | WITHIN | 0.1 KNOT |
| 3-10 KNOTS | WITHIN | 0.2 KNOT |
| OVER 10 KNOTS | WITHIN | 2% |

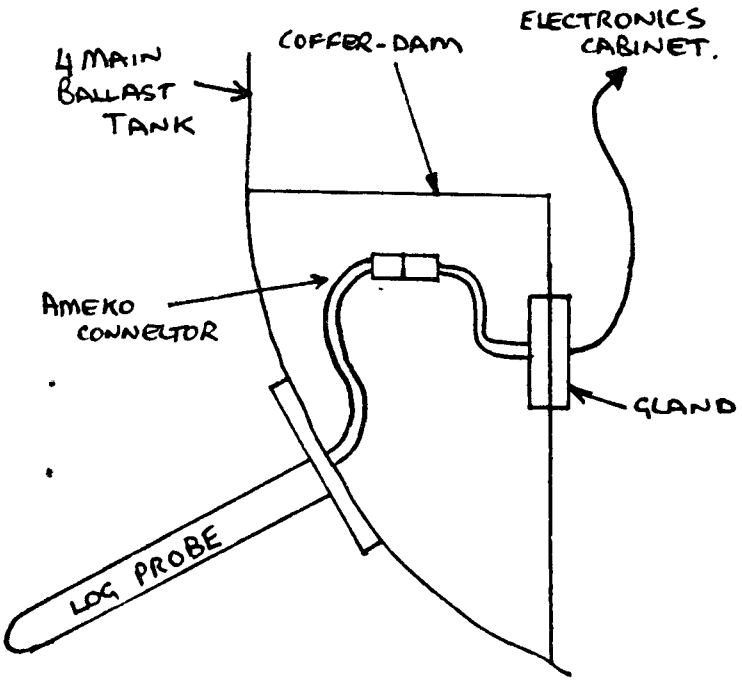
LOG VARIANTS:
(1) Standard.
(2) Transistorized.
(3) Solid State with L.E.D. readout. [in design stage].

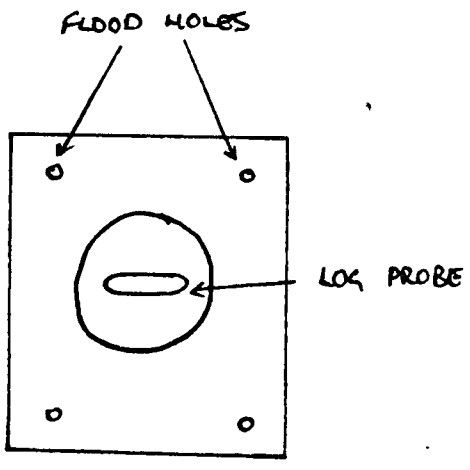
## ASSOCIATED UNITS

SPEED AND DISTANCE TRANSMITTER UNIT:
A Bulkhead mounted unit comprising of two main sections. The Left hand side contains the Electronics and the Right hand side containing the Speed and Distance Servo trays.

RODMETER:
The Sensing Head assembly is contained in a Fibre Glass Shell and consists of an AC supplied Iron Cored Coil embedded in Araldite within the shell. Two Bronze Pickups ( or buttons ), one on either side, flush mounted with the Shell are connected by cables to a Junction Box in the A.M.S.

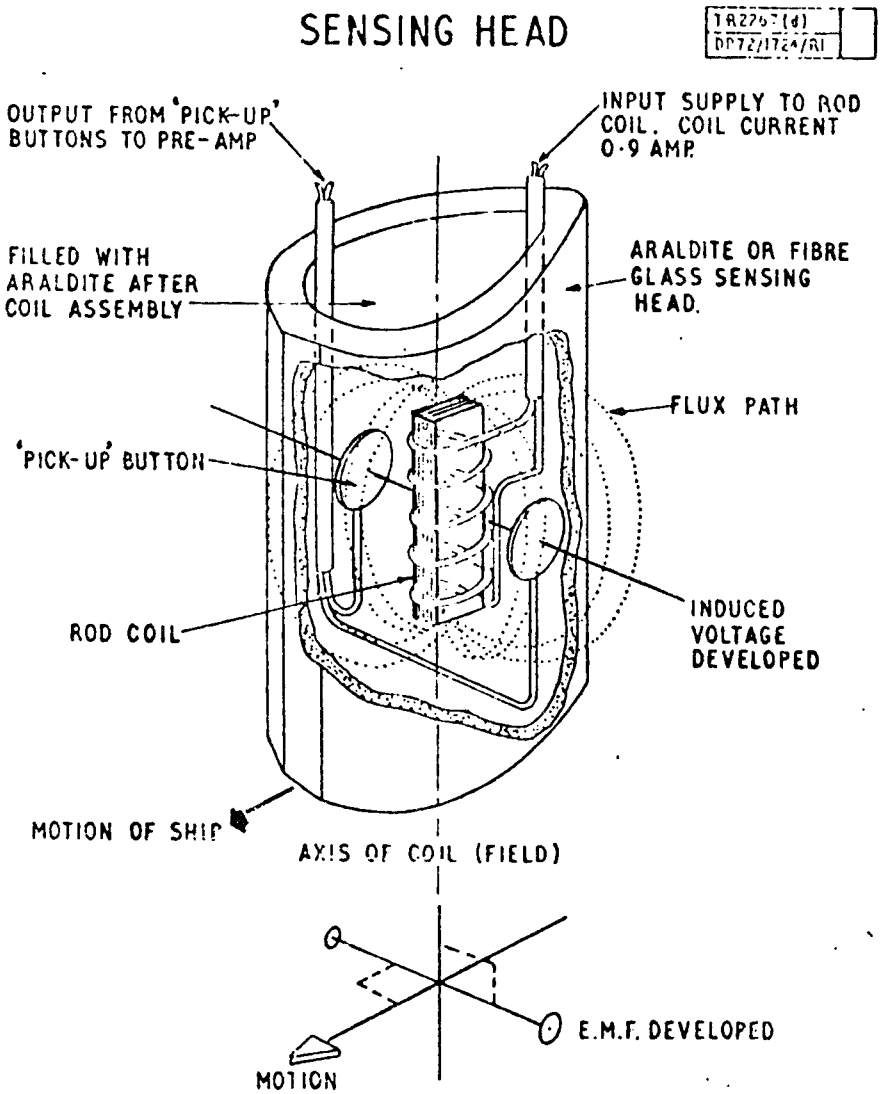
HULL FITTING:
The Rodmeter fitted on Submarines is bolted to the hull of 4 Main Ballast Tank. The electrical cable is passed through into a "COFFER DAM". The Coffer Dam is provided so that when the Rodmeter is to be replaced, AIR will not leak out of the Ballast Tank. (i.e. A Buffer between the probe and the Ballast Tank). The Coffer Dam has 4 Floodholes, ( about 50 cm from the Probe ), which allows the Pressure to equalize. A specially designed connector ( AMEKO ) connects the Probe to the Electronics Cabinet.



TRANSMISSIONS:
The number of Ships Speed Transmissions available from the Speed and Distance Transmitter Unit is increased by the use of a Re-transmission Unit. This utilises a single Synchro output from the S.D.T.U. to drive a servo unit connected to a series of gears which drive transmitting elements. Indication of ships Speed is provided by a dial visible through the cover.
Distance information can be relayed by Cam operated Micro Switches operating at rates of 100, 200 and 400 Pulses per Nautical mile.

SUPPLIES:
Normally 115V 60 Hz.
24 V DC.



PRINCIPAL OF OPERATION:
With the Rodmeter Vertical and moving Horizontally through the water at right angles to the Pickup Electrodes. The Magnetic flux produced by the current in the Coil is cut by the sea water acting as a conductor and a small EMF is set up across the electrodes. The EMF developed is proportional to the rate at which Flux cuts into the water, i.e. proportional to the ships velocity through the water.

RODMETER SENSITIVITY:
The outputs of different Rodmeters for the same speed are not necessarily equal. The Signal Voltage produced is of the magnitude 360 - 450 uV per Knot, although considered to have a nominal sensitivity of 400 uV/Knot. It may be necessary to change the sensitivity setting after having completed Calibration Trials to assess Log error or after changing a Rodmeter.

RODMETER ZERO COMPENSATION:
In using an AC supply, a small AC voltage will be developed in the signal circuit due to Transformer action, which will be very nearly in Quadrature (PHASE) to the signal voltage proportional to ship velocity. The small inphase component of this voltage due to transformer action measured in absolutely STILL water conditions must be balanced out otherwise a permanent error would persist over the whole range of speeds. This is achieved by the Rod Zero Potentiometer.

PRODUCTION OF SPEED:
The principal components are Preamplifier, Phase Conscious Rectifier, DC Power Amplifier, Split Field Servo Motor, Reset Potentiometer and Reset Correction Potentiometer.

Preamplifier:
The signal voltage from the Rodmeter is applied to the Primary of the input Transformer, T5, and stepped up approximately twice (X2) in the Secondary. A Resetting signal from the Trimmer Unit is applied to the Secondary in a sense which always tries to reduce the effective output of the Transformer to ZERO. The Algebraic Sum of these two signals is known as the CORRECTION signal and is applied to the first stage of a three stage CASCADE amplifier with gain control effected by varing the Negative Feddback applied over the three stages. The output of the third stage is Directly Coupled to a Cathode Follower which feeds the centre tap of the Phase Conscious Rectifier Transformer.

Phase Conscious Rectifier:
The output of the Preamplifier will have a phase relationship to the reference voltage dependant on Speed increasing or decreasing. The Reference voltage is developed by the Rodmeter Coil Current passing through a Resistor of value 1 Ohm. The Primary of the P.C.R. Transformer is connected across this resistor giving a Secondary voltage of 30V-0-30V. For steady conditions, say for one half cycle employing MR2 and MR4, the current flow in the lower half of the Transformer is counterbalanced by that in the upper half, thus the effective potential across capacitor "A" is nil, point "X" is at the same potential as -HT. The second half cycle will show that point "Y" is held at the same -ve potential for the same reason, using rectifiers MR1 and MR3 and capacitor "B". RV1 is included to balance out the effect of any component tolerance. The effect of a signal being passed to the Centre Tap of the Transformer is (dependant on PHASE) equivalent to shifting the Centre Tap away from the centre position, thus increasing the EMF at one end and decreasing it at the other. The current flow in opposite directions for each half cycle will now be unbalanced and a potential difference will appear across the Capacitors causing one to go Positive and the other Negative in respect to HT -ve, thus giving a potential difference between points "X" and "Y".

DC Amplifier:
The DC signal from the PCR is first modified by a Velocity Feedback signal from a Tacho Generator, then fed to a voltage amplifying stage. The Amplified output from this stage controls a pair of BEAM TETRODES with a common Cathode coupling and Anodes fed through opposing halves of the Speed Servo Motor Field winding. Hence, the motor Torque is proportional to the difference between the Anode currents.

DC Amplifier Continued:
Shaft rotation drives the Resetting Potentiometer fed with the Reference Voltage from the Trimmer Unit, thus a voltage proportional to speed is picked off and fed back, via the Trimmer Unit , to the Preamplifier Input Transformer to balance out the signal from the Rodmeter and hold the system at the indicated speed.

Trimmer Unit:
The Voltage Induced at the Sensing Head by the ships motion is in general proportion to the Rodmeter speed with respect to the water. But, the flow characteristics of the water past the Rodmeter ( whether Smooth or Turbulant ) and the Eddies created by the Hull shape all combine to distort the output from a TRUE LINEAR output. It follows that if a linear Resetting signal, developed by Shaft rotation for Speed, is used then a balanced condition will be reached when indicating an incorrect speed. To overcome this effect of the slight NONLINEAR output from the Rodmeter, the Resetting Potentiometer voltage must be allowed to apply a voltage proportional to the TRUE SPEED. This is achieved in the TRIMMER UNIT by employing a further network across the voltage developed to feed the Resetting Potentiometer. This Network consists of nine [9] Potentiometers connected across the Reset Correction Potentiometer. The outputs of the Wipers of these Linear Correction Potentiometers are taken to nine Taps on the Resetting Potentiometer, whose shaft is also rotated proportional to Speed, thus the voltage picked off at any instance will be related to the position of its Wiper Arm in respect to any two [2] Taps. The ends of the Reset Potentiometer are connected together and to the Common Rail so that the correction at ZERO and 40 KNOTS is always Zero. The output of the Correction Potentiometer is returned to the Trimmer Unit where it is mixed with the Reset voltage from the Resetting Potentiometer, so that the resultant voltage is made exactly proportional to the output of the Rodmeter for that particular Speed. The Indicator system covers a range of 0 - 40 KNOTS, but a complete shaft revolution of the Resetting Potentiometer is equivalent to a 50 KNOT range. The DEAD space is to allow for INITIAL ALIGNMENT considerations. It follows that at ZERO indication, the Resetting Potentiometer would hold a voltage that would drive the system below ZERO, unless balanced out. A signal of appropriate Phase and Magnitude is picked of by the Indicator Zero Potentiometer and mixed with the Reset and Resetting Correction signals in order to hold the system at indicated zero. The outputs of different Rodmeters at the same speed are not necessarily equal. This condition is overcome by feeding the output of the mixed Reset, and Indicator Zero signal to the Wiper of the Rodmeter Sensitivity Potentiometer, to permit variation of the Attenuation Ratio of these signals.

CALIBRATION TRIALS:
A series of runs over the measured distance must be made at speeds of 4, 8, 12, 16 and 20 Knots and at 4 Knot intervals to Maximum Speed. During the Calibration runs the ships actual speed over a measured distance is compared with the Indicated Distance from the LOG during the same period. The difference between the two readings is called the Numerical Log Speed Error and is plotted graphically.
The error result expressed as a percentage of true speed indicates the degree and sign of the correction to be applied. The dial markings on the Linearity Correction Potentiometers correspond to the effect the setting would have on indication. All calibration runs are completed before any corrections are applied, on applying corrections, check calibration runs are undertaken. It is possible that results will show errors indicating a basic percentage error. In this case, Rod Sensitivity Potentiometer setting would be revised and linearity corrections applied to the Linear Correction Potentiometers.

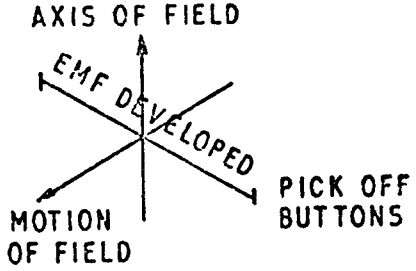
THE CALIBRATOR:
This is a built in facility on the standard system and in the Transistorised system it is a separate portable unit, however both units fulfil the same function. Its main purpose is to initially set up the electrical and scale zero postions of the nine Linearity Correction Potentiometers, which is essential prior to the ship carrying out calibration trials over the measured mile. Subsequently, and after the linearity corrections have been applied, the calibrator enables ships staff to check the accuracy of these settings.

TR2267(a)
DP72/1724/PT

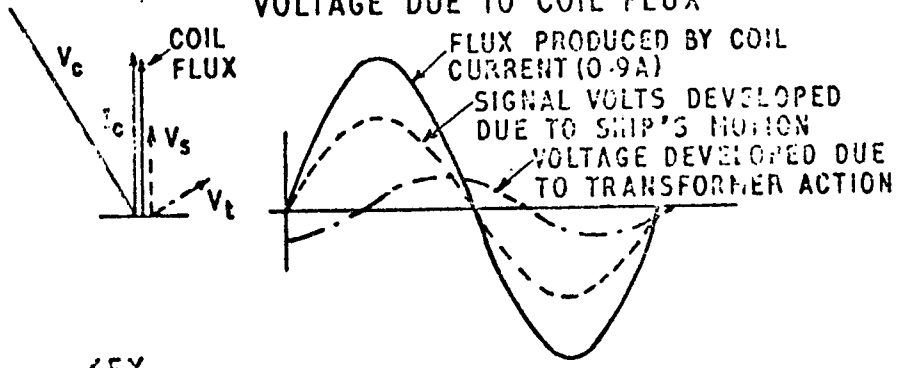
# ELECTRO – MAGNETIC LOG

## DEVELOPMENT OF ROD SIGNAL AND ROD ZERO COMPENSATION

PRINCIPLE EMPLOYED
(FARADAYS' LAW)




THEORETICAL DEVELOPMENT OF VOLTAGE DUE TO COIL FLUX



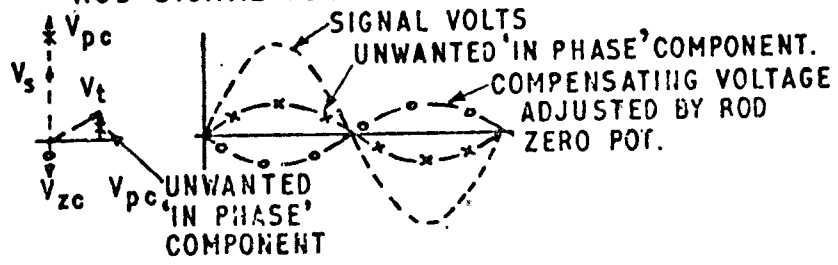

KEY

$V_c$ – COIL VOLTS
$V_s$ – SIGNAL VOLTS
$V_t$ – VOLTAGE DUE TO TRANSFORMER ACTION
$V_{pc}$ – 'IN PHASE' COMPONENT DUE TO TRANSFORMER ACTION
$V_{zc}$ – COMPENSATING VOLTAGE REQUIRED

NOTE:–

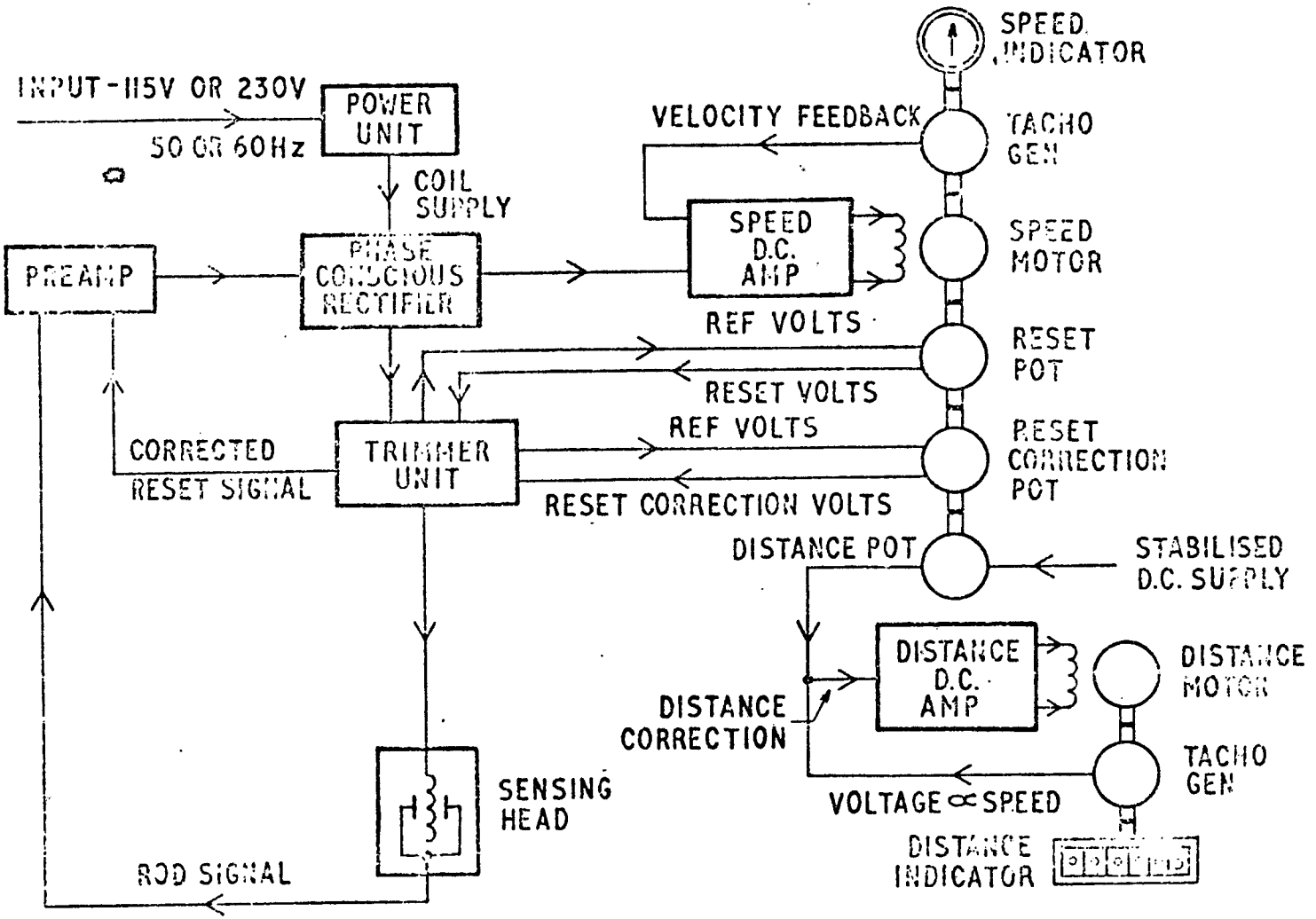
1. SUPPLY TO COIL IS 115V 60 Hz – CURRENT IN COIL IS ADJUSTED TO 0·9 AMPS.
2. THE UNWANTED 'IN PHASE' COMPONENT IS MEASURED & COMPENSATED IN ABSOLUTE STILL WATER.

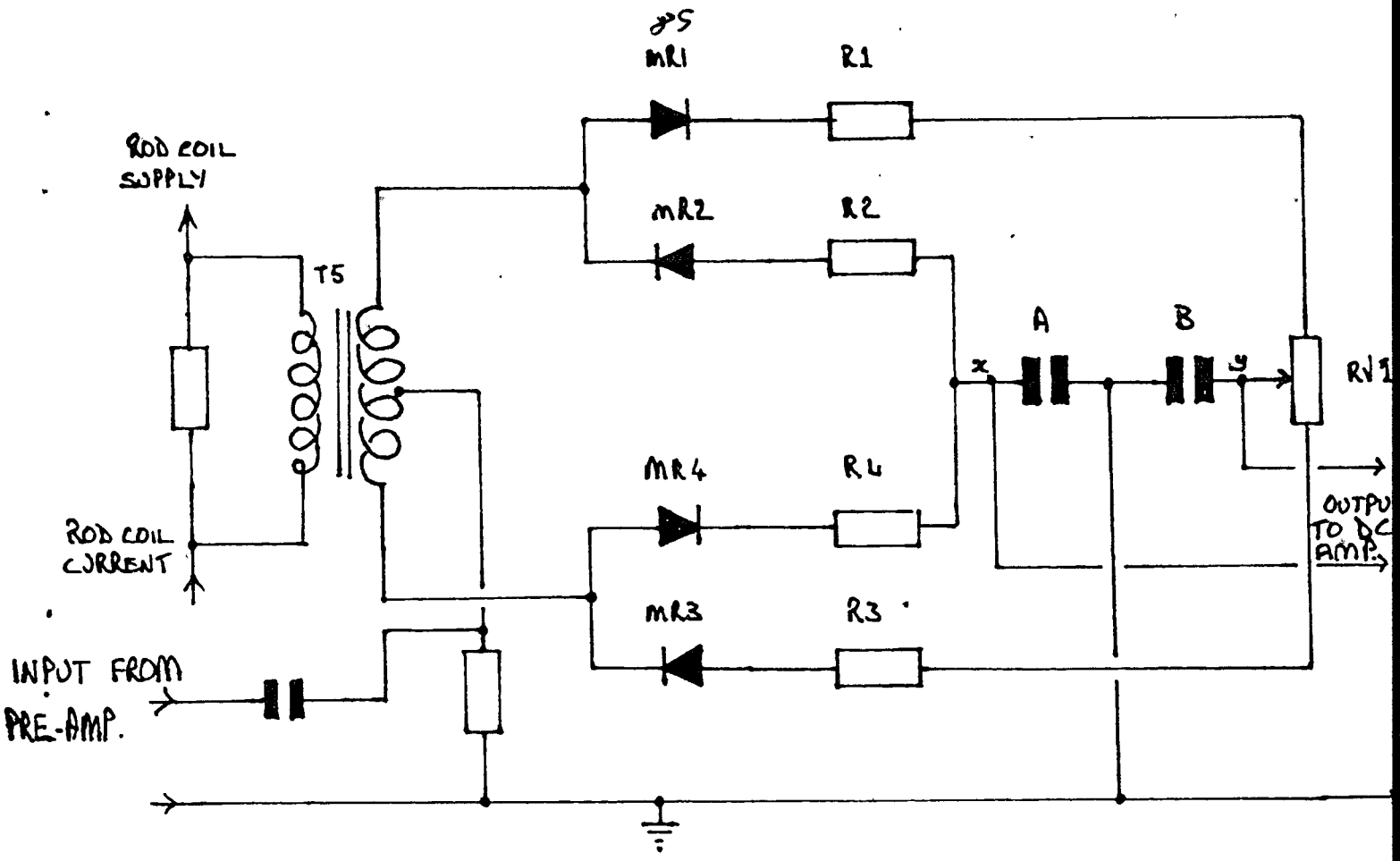
ACTUAL DEVELOPMENT OF CORRECTED ROD SIGNAL VOLTS



# ELECTRO - MAGNETIC LOG
## SCHEMATIC ARRANGEMENT

TR.1895
O.P. 74/6./13



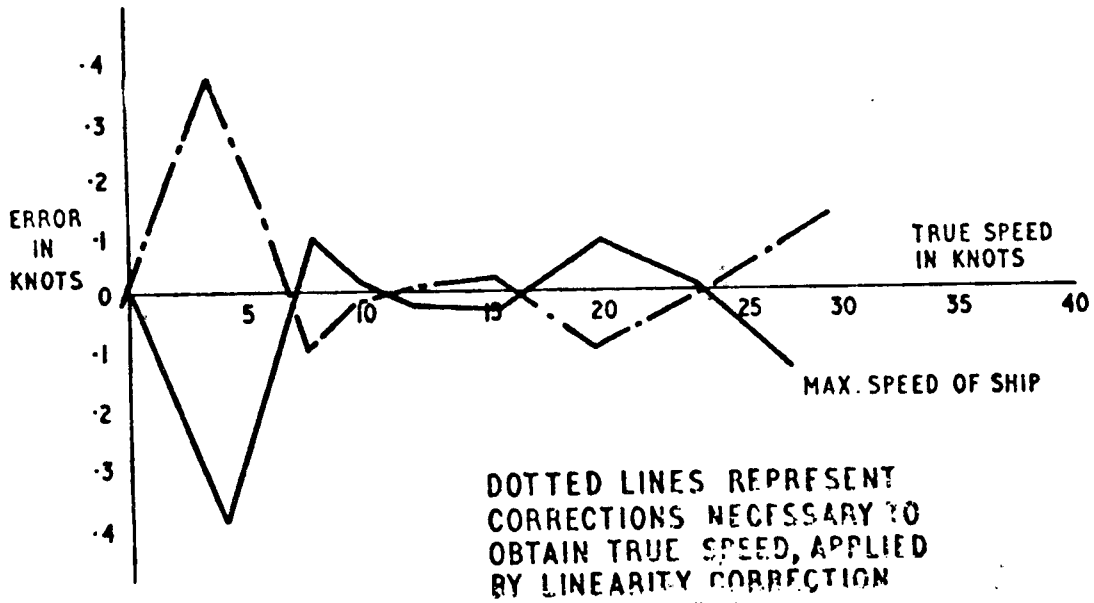



PHASE CONSCIOUS RECTIFIER

TR2267(c)
DP72/1724/R1

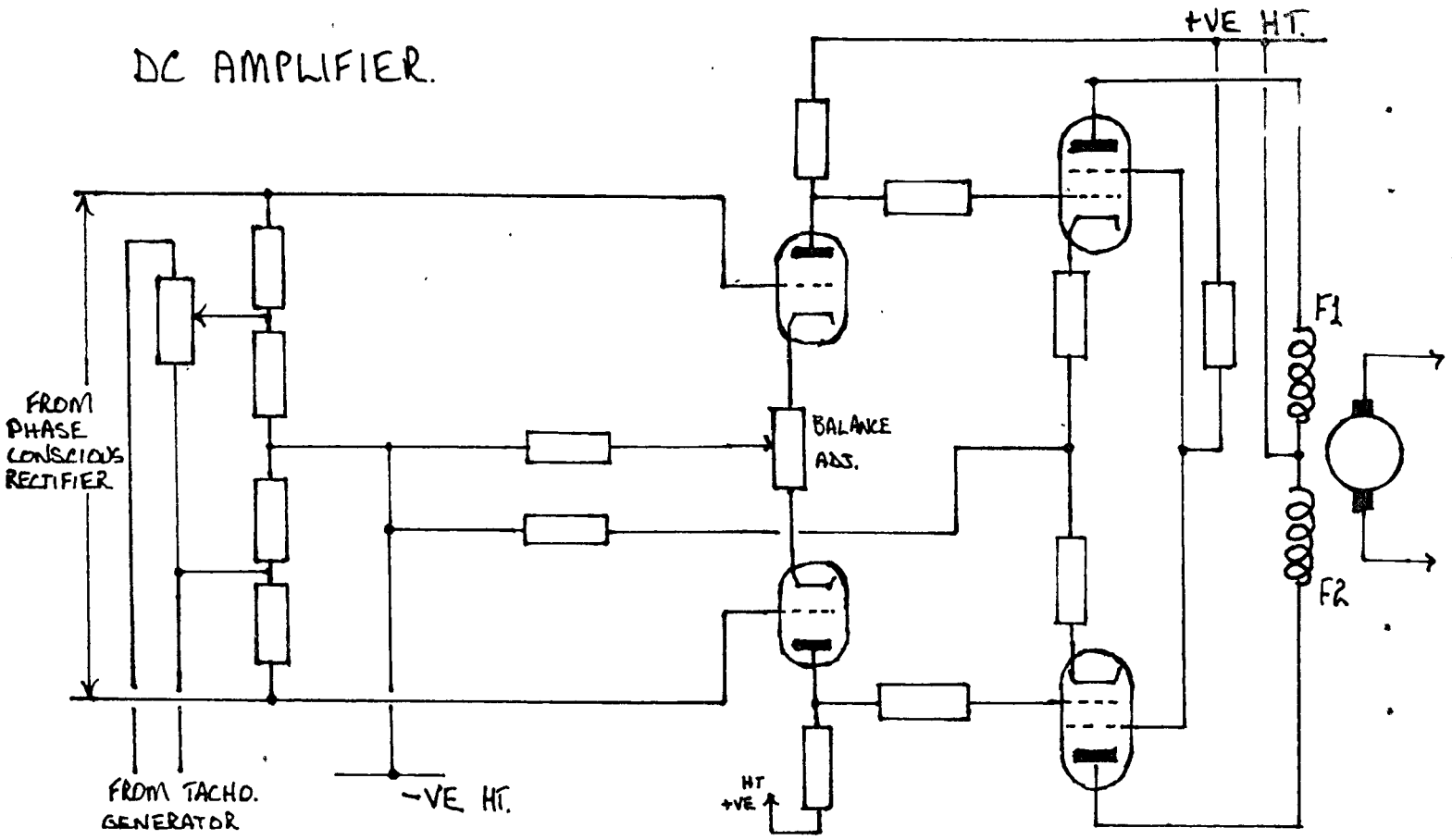
## ERROR GRAPH (TYPICAL)

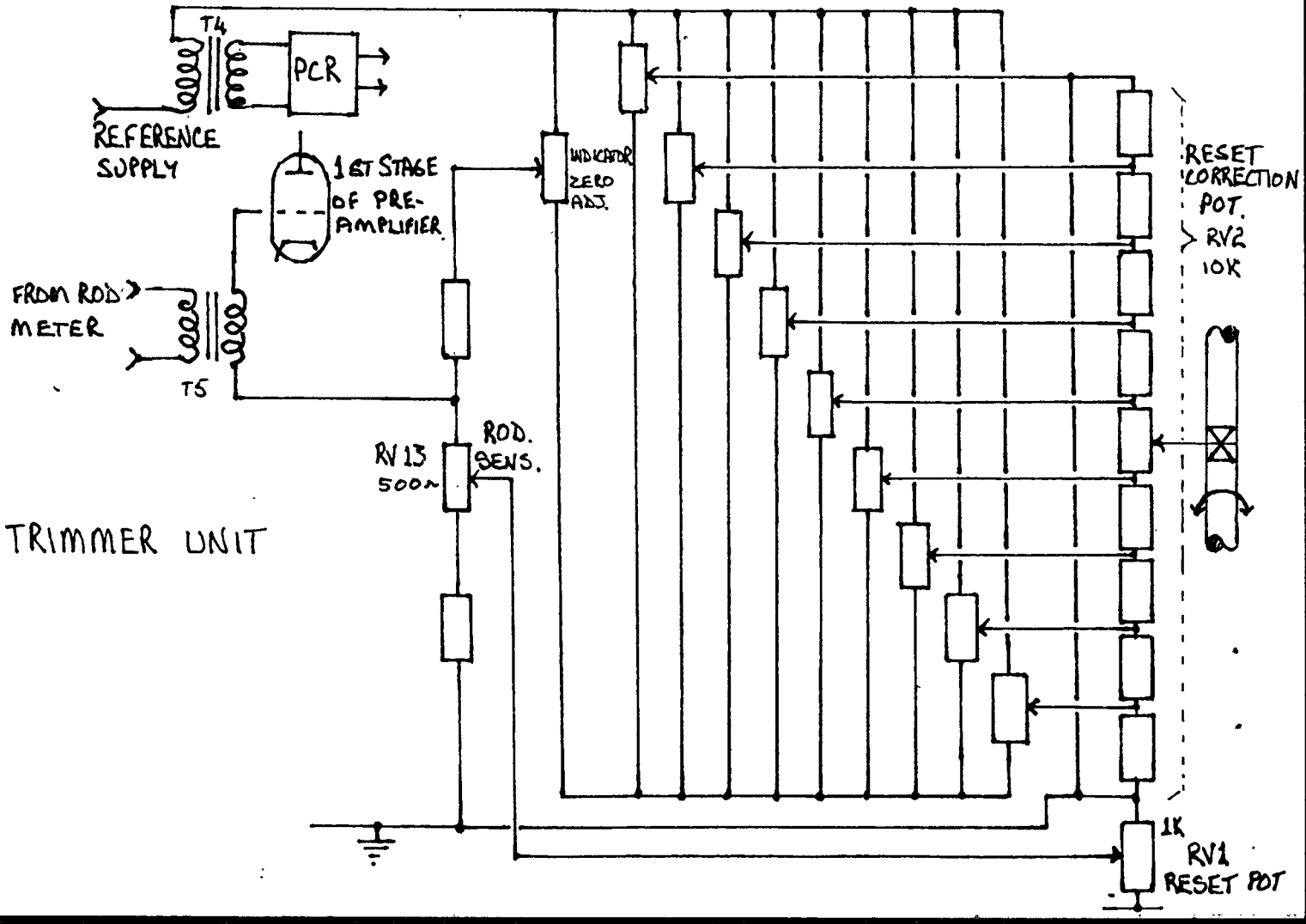
OBTAINED DURING RUNS OVER MEASURED MILE




DOTTED LINES REPRESENT CORRECTIONS NECESSARY TO OBTAIN TRUE SPEED, APPLIED BY LINEARITY CORRECTION POTENTIOMETERS.

# DC AMPLIFIER.



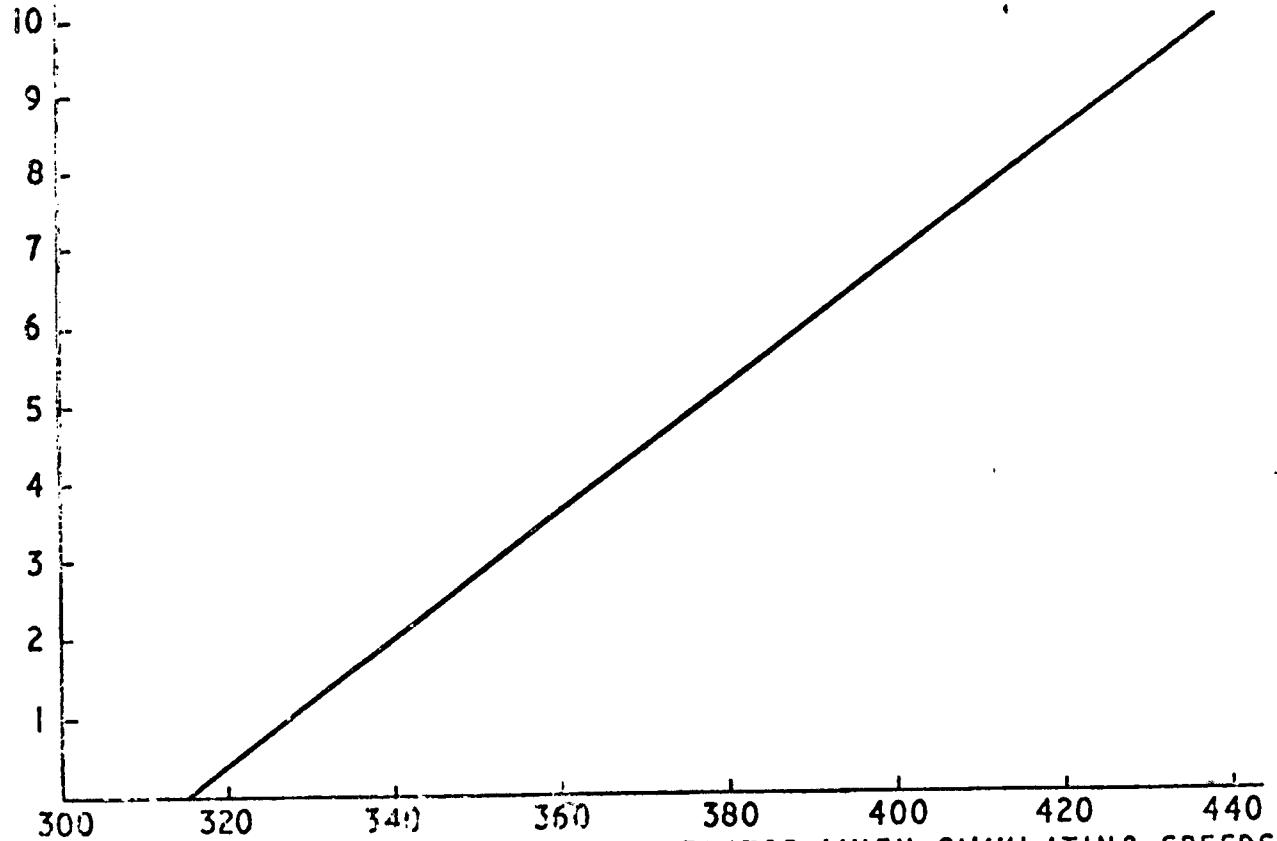




TRIMMER UNIT

# ELECTRO–MAGNETIC LOG
## ROD SENSITIVITY CALIBRATION GRAPH
(SUPPLIED WITH LOG EQUIPMENT)

TR2267(B)
DP72/1725/R1

ROD SENS DIAL SET SUPPLIED WITH SPEED AND DISTANCE TRANSMITTER




TO OBTAIN ACCURATE OUTPUTS FROM THE CALIBRATOR WHEN SIMULATING SPEEDS IN STEPS OF 4 KNOTS, THE CALIBRATOR DIAL (RV1) SHOULD BE INITIALLY SET TO 2/65 AND THE ROD SENSITIVITY DIAL (RV13) TO 7/00.
WHEN CALIBRATING DISTANCE, THE DISTANCE CALIBRATION DIAL (RV2) SHOULD BE INITIALLY SET TO 6/87 AND THE CALIBRATE LINEAR CORRECTION DIAL SETTING (RVII) SET TO 2·00.

# OPERATING INSTRUCTIONS

(1) Switch ON AC supply.
(2) Switch on 24 Volt DC supply for transmission.
(3) Wait 15 minutes (warming up period).
(4) Switch on ROD POWER.
Check ROD CURRENT.
(5) Place meter switch to SPEED.
(6) Check balance of speed amplifier. Make SG adjust RV3 as necessary. Release SG.
(7) Switch on SPEED ARMATURE.
(8) Operate switch SH and check directional sense of speed servo.
(9) Place meter switch to DISTANCE and check balance of distance amplifier. Make switch SD. Adjust RV1 as necessary, release SD.
(10) Switch on DISTANCE ARMATURE
(11) Operate switch SE and check directional sense of DISTANCE servo.
(12) Operate DUMMY signal switch SK to PLUS 1 KNOT. The SPEED indicator dial should read 1 KNOT ± 0.1 KNOT.
(13) Operate DUMMY signal switch to +10 KNOTS. SPEED indicator dial should read 10 KNOTS ± 0.1 knot.
(14) If satisfactory, place DUMMY signal switch to RUN, switch OFF Speed and Distance Armatures and Rod Power Supply.

ROUTINE FOR PUTTING LOG INTO OPERATION:

The following supplies are switched ON.
(1) AC (Left on from previous checks)
(2) 24 Volt DC
(3) Rodmeter Power
(4) Speed Armature
(5) Distance Armature

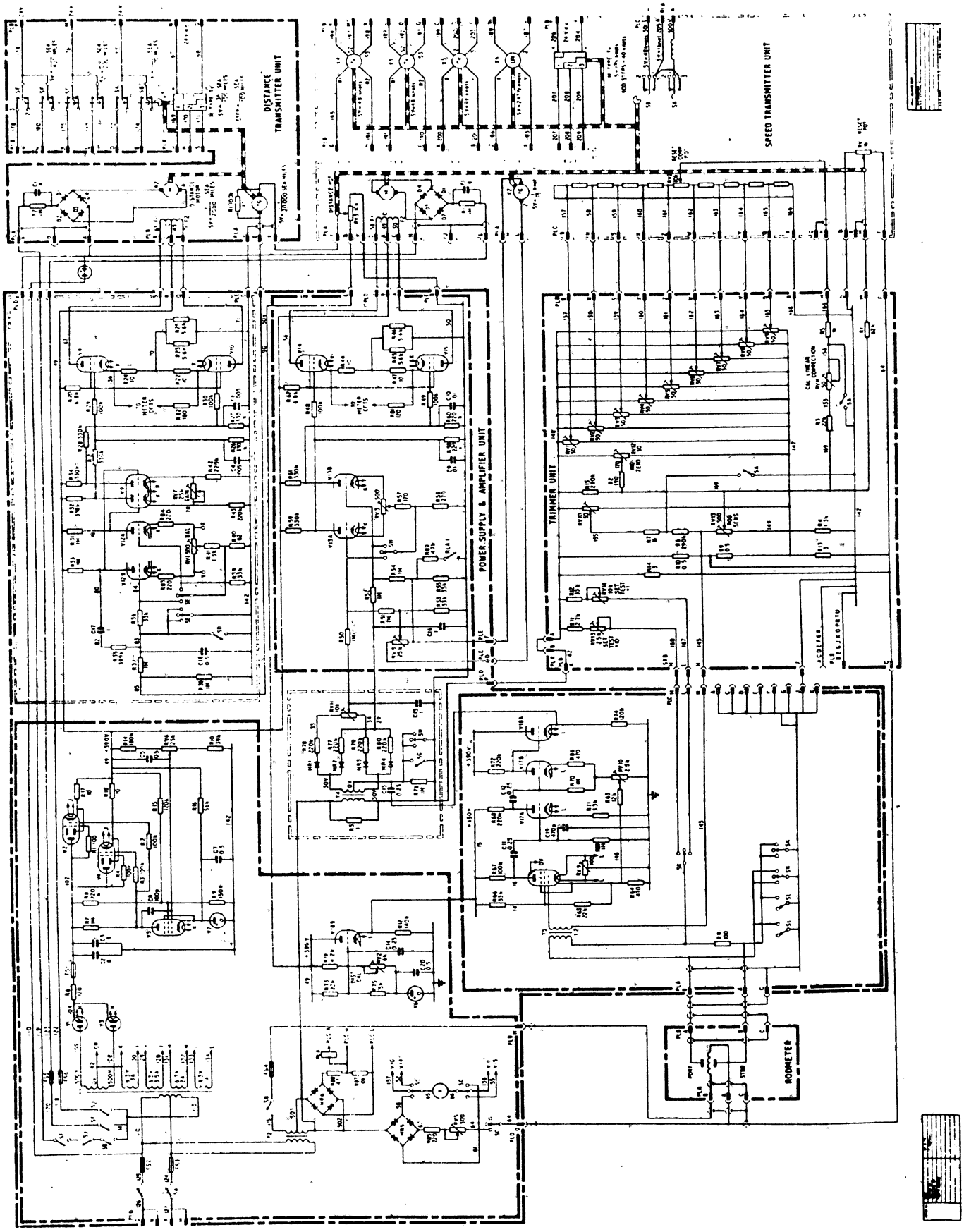
The indicator lamp (230 VOLT NEON) in the Speed and Distance Transmitter Unit will only light when circuits 1,3,4 and 5 have been energised.

NOTES:
Do not switchon Rodmeter coil supply when the Rodmeter is out of the water or when cables are disconnected. If power is supplied to Rodmeter coil when Rod is not in water, overheating of the Rod coil will occur.

If power is required to operate the system without the Rodmeter, a dummy load resistor must be inserted in lieu of the Rod Coil.
CODOCK HAVE THIS DUMMY LOAD

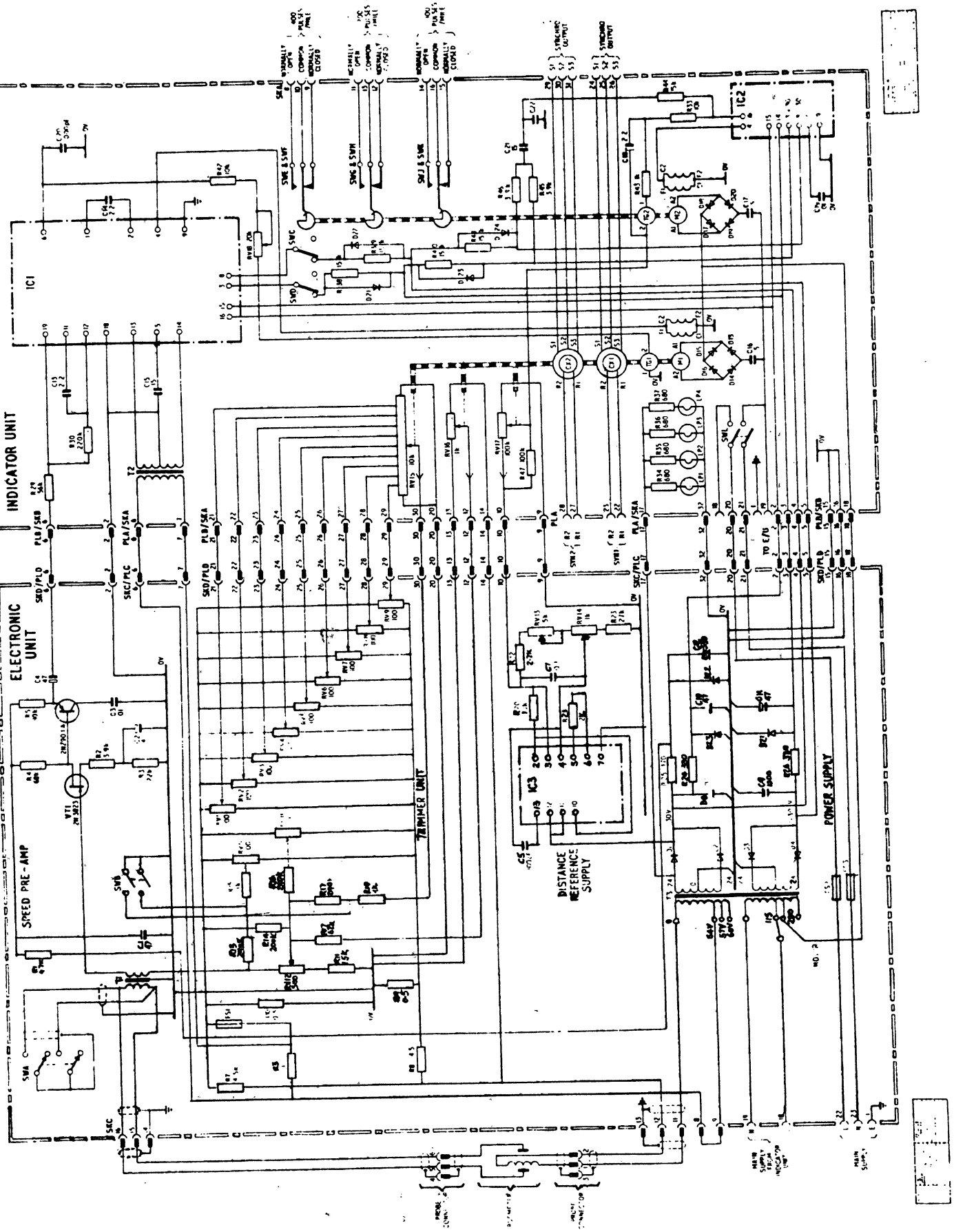
Cat No 2331
DP 64/5369

# ELECTRO-MAGNETIC LOG — CIRCUIT DIAGRAM



Cat. No E 2330
D.P. 73/1511

# E. M. LOG (TRANSISTORISED) CIRCUIT DIAGRAM

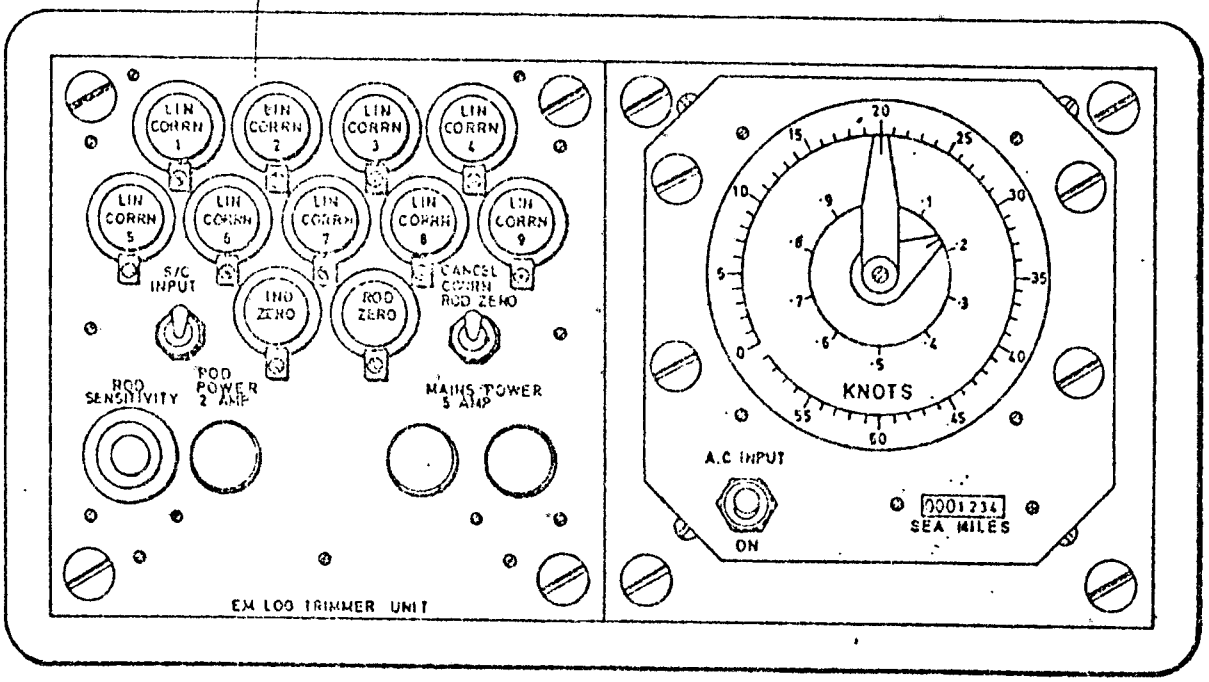


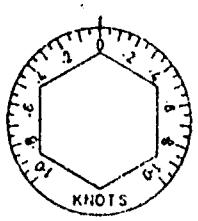
# TRANSISTORISED ELECTRO-MAGNETIC LOG

## TECHNICAL DESCRIPTION

INTRODUCTION (Fig 3.1)

1. The speed and distance transmitter unit comprises a console, into which is plugged an indicator unit and a trimmer unit, and a calibrator which is stowed separately. The equipment housed in the console incorporates two servo systems, a positional servo and a velodyne servo. The former provides a synchro transmission of speed and the latter, controlled by the positional servo, produces a series of dc pulses representing distance travelled. Visual indication of speed is provided by a clock type dial calibrated in knots; a numerical register displays distance travelled in sea miles. The calibrator is used when injection of a fixed known speed signal is required.




DIAL ENGRAVING FOR 'LIN CORRN' 1 TO 9

DIAL ENGRAVING FOR 'ROD ZERO' AND 'IND ZERO'

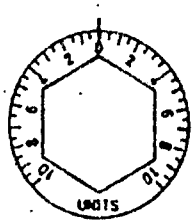



FIG.3.1 SPEED AND DISTANCE TRANSMITTER UNIT - FRONT PANEL

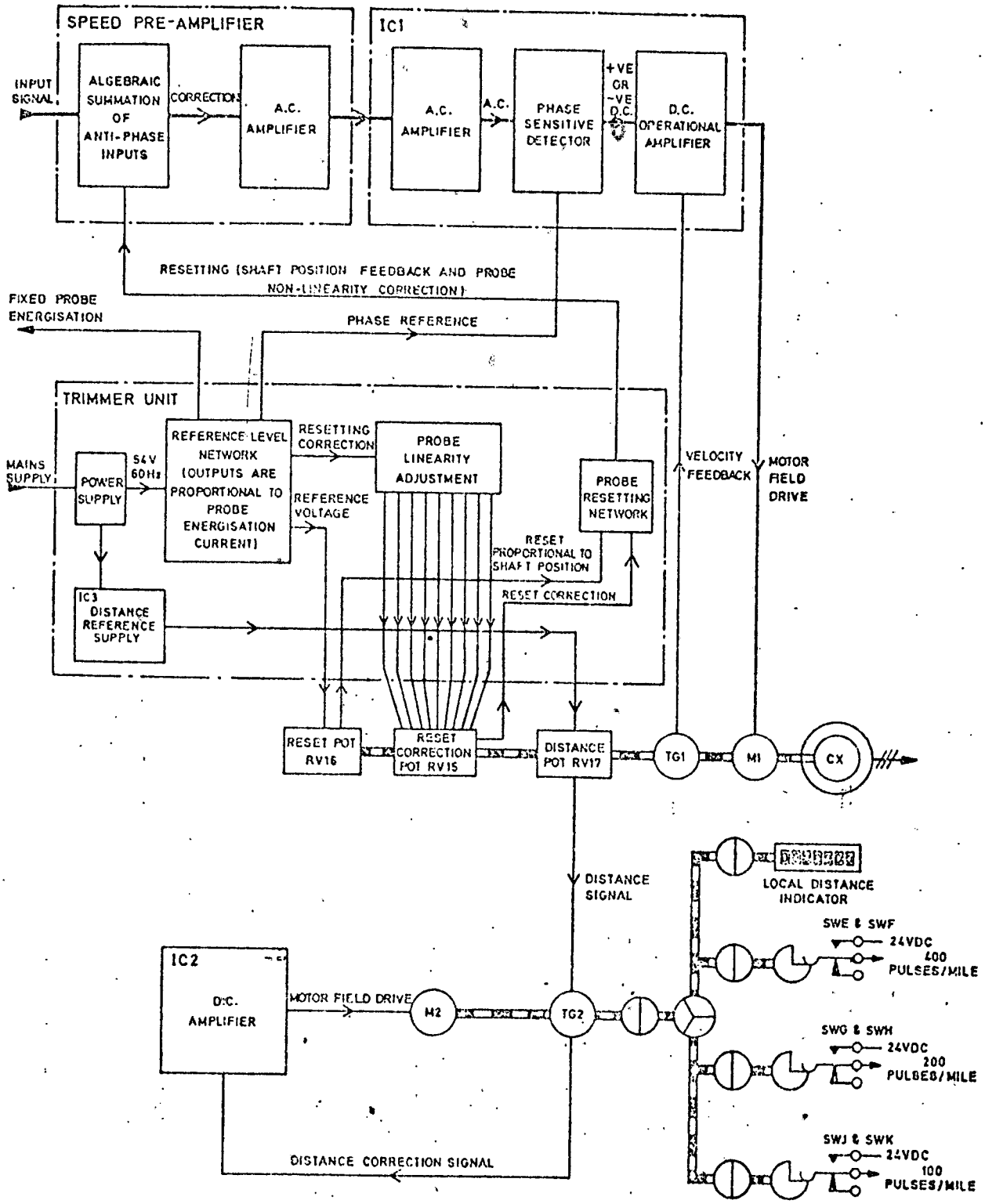



FIG.3.2 SPEED AND DISTANCE TRANSMITTER UNIT-BLOCK DIAGRAM

FUNCTIONAL DESCRIPTION (Fig 3.2)

2. The input to the positional speed servo is pre-amplified and fed via an ac amplifier to a phase-sensitive detector (PSD). The PSD compares the phase of the amplified input signal with that of a phase reference voltage to produce a dc output which is amplified to drive the motor M1 on the speed shaft. Tacho generator TG1 provides velocity feedback.

3. Synchro transmissions proportional to speed are provided by two externally excited control transmitters geared to the speed shaft.

4. A reset potentiometer RV16 provides an anti-phase feedback proportional to shaft position to complete the servo loop. Potentiometer RV15 is used to correct any non-linearity in probe signal due to inconsistency of water flow past the probe.

5. The input to the velodyne distance servo is a voltage proportional to speed obtained from the distance potentiometer RV17 coupled to the speed shaft. Tacho generator TG2 provides velocity feedback. Six cams driven via gearing from the distance shaft, each operate a micro switch which interrupts an external 24V dc supply to provide three different pulsed outputs representing distance.

6. To provide local indication of speed a mechanical output from the speed shaft drives a clock type dial giving readings in knots and tenths of a knot to a maximum of 60 knots. A drive from the distance shaft is connected via gearing to a cyclometer type display giving readings in sea miles and tenths of a sea mile to a maximum of 99,999.99 sea miles.

CIRCUIT DESCRIPTION (Fig 3.11)

Power Supplies

7. The 115V 60Hz is applied to SKC pins 22 and 23 of the electronic unit and, via FS2 and FS3 to the Mains On/Off switch in the indicator unit. Pin 1 is connected to an external earth. A supply is then taken from the indicator unit, via SKC pins 18 and 19, to transformer T3 in the electronic unit. The line side is also taken direct to two rectifying circuits comprising C16, C17 and D13 to D20 inclusive. The neutral to these circuits is routed via the main input transformer. Both circuits supply power to the servo motor armatures.

8. Transformer T3 has three secondary windings, two of which are centre tapped, rectified by diodes D1, D2, D3 and D4, and smoothed by capacitors C8 and C9 to provide a +30V dc and -30V dc supply with respect to the OV rail. A supply for the indicator lamps is teken from one secondary before rectification.

9. The unstabilised 30V +ve and -ve supplies are fed to IC1 and IC2 in the indicator unit and IC3 in the electronic unit together with a 12V +ve and -ve supply derived from the 30V lines using R24, D23, C10, and R26, D21 and C11 respectively. A +20V supply derived via R25, D22 and C12 provides power to the speed pre-amplifier. One further +30V supply provides the input to a series stabiliser circuit incorporating IC3 in the electronic unit, which provides a stabilised distance reference supply.

10. The third secondary winding of T3 provides energisation for the fixed probe or rodmeter.

Calibrator (Fig 3.12)

11. The calibrator is connected in circuit when required and enables signals from 0 to 60 knots, in 6-knot steps, to be injected into the speed servo control circuit. The trimmer and indicator units are disconnected from the console assembly. The two units now obtain their supply via pins 22, 23 and 1 of test lead PLC. The calibrator input is derived from the dummy load (simulating the rodmeter coil) current which is passed through resistor R1. The voltage developed across R1 is applied to the primary of transformer T1. Potentiometer RV1 is connected across a portion of T1 secondary, enabling adjustment of the transformer output. The range of adjustment is sufficient to produce the equivalent of 60 knots at sensitivities from 0.4mV/knot to 0.45mV/knot.

12. A statement of rod sensitivity dial settings (RV14) for various sensitivities and a straight line connecting these points are supplied with the test records for each equipment.

Calibrator connections

13. To connect the calibrator for use the trimmer and indicator units must be withdrawn from the console assembly. The coil/signal test lead assembly and the dummy load are connected as shown in Fig 3.12 and the Knots switch set to the required position.

REFERENCE SUPPLIES

14. Since the fixed probe input signal to the speed servo is proportional to the current through the probe coil when the unit is in use in the system it is necessary, for accuracy of speed measurement, that all reference signals used within the SDTU are also proportional to probe coil current thereby nullifying variation of supply voltage. This is achieved by using as a source of reference the voltages developed across resistors R6 and R7 which are in series with the probe coil.

Integrated Circuit Reference Supply to IC1

15. This supply is derived from the voltage developed across R6, which is sampled by the primary of transformer T2 and fed to a phase sensitive detector within IC1. It is proportional to and in phase with the fixed probe input signal.

Reset Reference Supply to RV16

16. The reset reference supply is developed between the junction of R7, R8 and the OV rail. It is applied across potentiometer RV16 to provide a linear resetting signal which is taken from the wiper.

Trimmer Unit Reference Supply

17. This supply is obtained from the voltage developed across R7 and is used to provide a reference voltage for a number of system adjustment potentiometers.

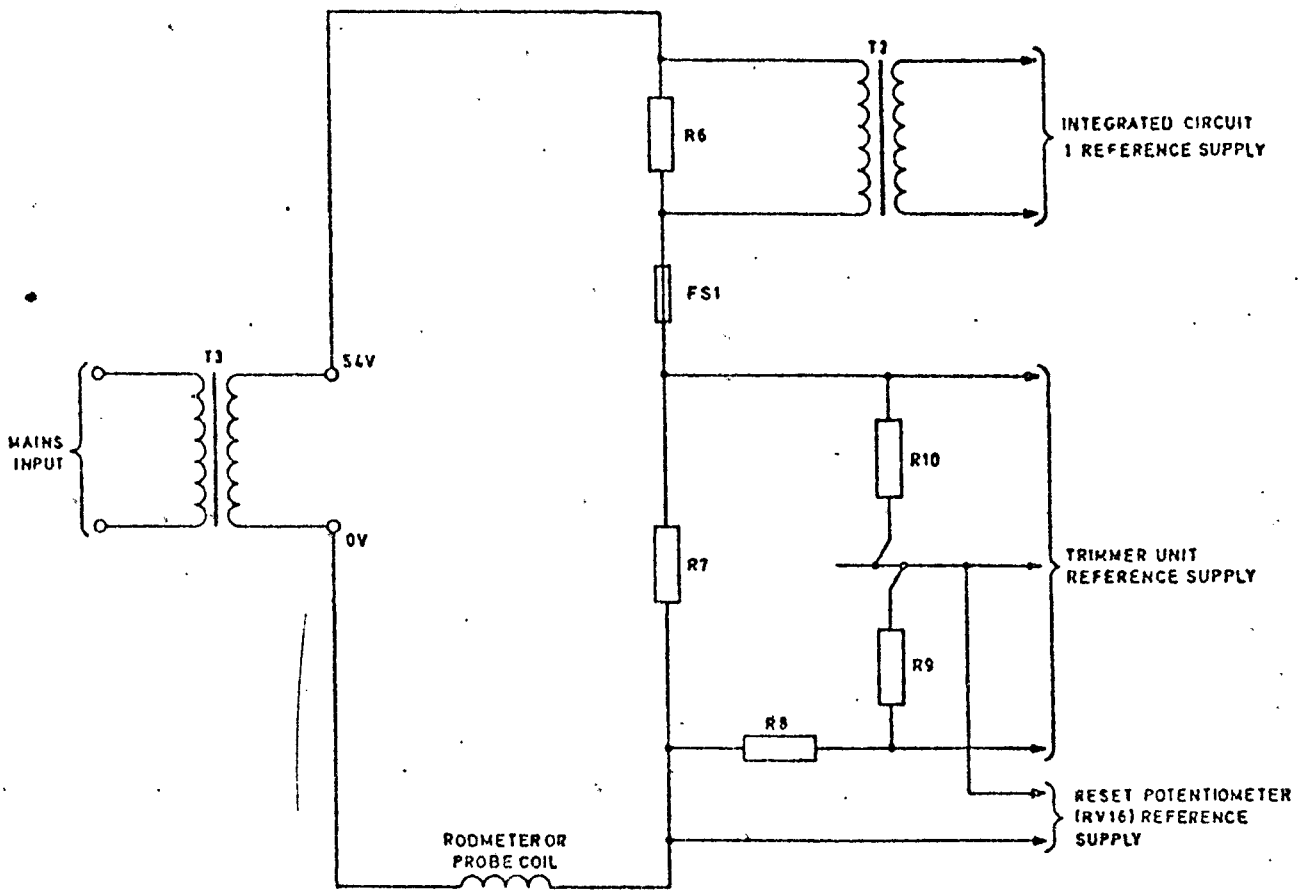



FIG. 3.3 REFERENCE SUPPLIES

ADJUSTMENT POTENTIOMETERS (TRIMMER UNIT)

18. Several adjustment potentiometers are provided in order to compensate for the following:

Non-Linearity of Signal Speed (RV1-RV9)

19. A signal in phase with the linear resetting signal (para 16) is developed across R9 and a signal of opposite phase is developed across R10. Since the linearity correction potentiometers RV1 to RV9 inclusive are connected across R9 and R10 ar in or out of phase signal can be applied by adjustment of the potentiometer wiper outputs to the various tappings on the Reset Correction potentiometer RV15. RV15 has nine equally spaced tappings which correspond to 6 knot intervals.

Rod Zero (RV10) - Signal at Zero Speed

20. Electrical zero of the Reset potentiometer RV16 is approximately minus 2.6 knots, in order to provide a + or - adjustment for probes with different 'zeros', therefore a signal is required to balance that received from RV16 when the probe output is zero at zero speed. This signal is derived via potentiometer RV10 which is connected across the trimmer unit reference supply. Adjustment of the wiper

will allow the input to the servo loop input transformer T1 to be set at the level required to provide zero signal at no speed.

Instrument Zero (RV11) - Instrument Reading with Zero Signal Input

21. A signal obtained from RV11 is applied to the input of the amplifier in the speed servo to nullify any amplifier output under no signal conditions (ie balance control).

Varying Rod Sensitivities (RV12)

22. Outputs of fixed probes at the same ship's speed are generally unequal and therefore a means of adjusting the combined resetting signal to compensate is required. The outputs of the Reset potentiometer RV16, Reset Correction potentiometer RV15 and the probe zero potentiometer RV11 are therefore all taken to the per of the Rod Sensitivity potentiometer RV12, thereby allowing simultaneous justment of all three signals. In Type 21 Frigates only, the output from RV16 is further attenuated by the insertion of R12A (6.8k ohms, NS No. 5905-99-013-5117) between the junction of R12, R14, R16 and R17 and wiper of R12.

23. The Cancel Corrn and Zero switch SWB provides a means of shorting the instrument zero and resetting correction signals during setting up procedures.

SPEED SERVO SYSTEM

24. The input to the speed servo system is termed the 'speed correction signal' and is the sum of the fixed probe input and the linear reset signal, which are in phase-opposition. The speed correction signal is applied to a two stage speed preamplifier comprising VT1, VT2 and associated components. The signal is fed to the gate of VT1, a field effect transistor the drain of which is directly coupled to the base of VT2. Feedback is provided via R2. The output of VT2 is developed across R5 and d via C4 to the integrated circuit assembly IC1.

25. IC1 comprises three circuit elements, a two stage ac amplifier, a phase-sensitive detector (PSD) and a two stage dc amplifier. First stage gain is fixed externally by R29, R30 and the output is coupled via C13 to the second stage which develops the final gain. The ac amplifier output is coupled via C14 to a differential amplifier element which together with a demodulator element comprise the PSD. When the phase of the amplified speed correction signal reverses relative to that of the reference voltage (para 15) the polarity of the PSD output also reverses to provide a + or - half sinewave output which is smoothed by C15. The smoothed signal is fed to the dc amplifier comprising two elements. The first, a differential amplifier receives the PSD output together with the velocity feedback signal from the speed tachogenerator TG1 which is fed to IC1 pin 6 via RV18. The differential amplifier output is fed to the second element, a class B output stage, the power output of which is routed via IC1 pin 4 to the field winding of M1 to drive the speed servo motor.

26. A mechanical limit stop is arranged to operate on the speed servo motor shaft which prevents the local speed indicator from reading less than minus 2.5 knots or more than 60.3 knots. The mechanical limit stop also actuates limit

switches SWD or SWC at minus 2.5 or plus 60.3 knots, respectively, thereby interrupting the positive or negative supply to the appropriate output transistor of IC1. When the polarity of the PSD output changes M1 will operate in the reverse direction out of the mechanical stop. The supply to the corresponding output transistor is connected via the other limit switch. Four 15 ohm resistors, R38 and R39, and R40 and R41 are connected in series with the 30V supplies to IC1 and IC2, respectively. These resistors limit to 2A, the current flowing should the two output transistors of IC1 and IC2 be turned on simultaneously. Diodes D21 to D24, connected across these resistors prevent spurious voltage peaks reaching either pair of output transistors in IC1 or IC2 when TG2 operates. Phase advance feedback is applied to input pins 3 and 8 of IC2 via R44, R45, R46, C21 and C22.

27. The shaft of the speed servo motor M1 is mechanically coupled to a three gang potentiometer assembly RV15, RV16 and RV17. The motor drives the reset potentiometer RV16 in the direction required to reduce the speed correction signal. When the speed correction signal is zero, ie when the reset and rod signals are equal, there is no output from integrated circuit IC1 and consequently the servo motor is stationary. The local speed indicator dial is mechanically coupled to RV16 and is calibrated to indicate ship speed in knots. RV15 is the reset correction potentiometer and RV17 provides an output proportional to indicated speed which is supplied to the distance servo.

28. Two synchro transmitters, SYN 1 and SYN 2, are geared to the speed servo motor shaft to provide synchro transmission outputs.

DISTANCE SERVO SYSTEM

29. A signal is taken from the wiper of the distance potentiometer RV17 which is fed with a stabilised dc voltage from the distance reference supply. Since the shaft of the speed servo motor M1 is mechanically coupled to RV17 this signal will be proportional to indicated ship's speed. The signal from RV17 and that from tacho-generator TG2, which is proportional to the speed of the distance servo shaft, together form the distance correction signal.

30. The distance correction signal is fed via a tacho-ripple filter, R33, R43 and C18, to pin 16 of the integrated circuit assembly IC2. This assembly comprises a high gain amplifier directly coupled to a power output stage which is routed via IC2 pin 4 to the field winding of the distance servo motor M2. Speed of the distance servo motor is therefore dependant on the magnitude of the amplifier output which varies according to the magnitude of the distance correction signal. Since this signal is proportional to indicated speed the number of revolutions of the motor shaft in a given time will be proportional to distance travelled. Coupled to the shaft via suitable gearing are a local distance display register and three pairs of cam-operated micro switches SWE and SWF, SWG and SWH and SWJ and SWK which provide 400, 200 and 100 make/break per sea mile respectively.

Distance Reference Supply

31. This is a stabilised voltage supply for the distance potentiometer RV17. Stabilisation is provided by integrated circuit IC3, a monolithic integrated voltage regulator. This assembly comprises four circuit elements, a temperature

compensated reference amplifier, an error amplifier, a power series feed transistor and a current limiter. The reference voltage output (pin 6) from the reference amplifier stage is connected via R21 to the non-inverting input (pin 5) of the error amplifier stage. This reference is matched by the output reference voltage applied to the inverting input (pin 4) of the error amplifier stage via the voltage divider chain R22, RV13, RV14 and R23. A change in the external load will cause the error amplifier to apply a signal to the series feed transistor, thereby increasing or decreasing the line impedance to restore the voltage to its original level. The voltage developed across R20 is fed back to pins 2 and 3 of the IC to provide current limiting. Potentiometer RV14 permits limited adjustment of the output voltage for distance calibration.

# ELECTROMAGNETIC LOG CALIBRATION

## METHOD 1

The EM log Calibration is to be conducted using the Jervis Bay Sound Range plotting and timing facilities.

(A) PORT or STBD Probe. Runs at 4, 8, 12 and 16 knots are to be carried out surfaced on the Sound Range. During the runs, the results are to be recorded in the table.
(B) PORT or STBD Probe. Calibrated by comparison with the Calibrated probe. This comparison to be achieved by running the submarine dived at a steady depth, course and speed and noting the time taken to register a short distance (about 0.5 sea miles), ie, averaged speed as recorded by the Calibrated Probe. Immediately carry out the same recording with the Uncalibrated probe; speed depth and course remaining constant throughout. These records should be taken at several speeds (preferably 4, 8 and 12 knots) and from comparison, difference in setting for Rod sensitivity, indicated by overall percentage error, and linearity (errors above and/or below overall percentage error) between the Calibrated and Uncalibrated probes can be assessed and applied as necessary, when transfering from the PORT probe to the STBD probe.
It should be noted that since comparison only is being made, there is no requirement for reciprocal runs over a measured distance, but as stated above, runs on one probe and then the other must follow each other immediately and speed, course and depth must be unchanged throughout.

## METHOD 2

The EM Log Calibration is to be conducted using the Mini Ranger.

(A) PORT or STBD Probe. Runs at 4, 8, 12 and 16 knots are to be carried out surfaced. During the runs, the results are to be recorded in the table.
(B) PORT or STBD Probe. Runs are to be carried out as in (A), however, it should be noted that a comparison only is being made. Differences in settings for Rod sensitivity, indicated by overall percentage error and linearity (errors above and/or below overall percentage error) between probes, can be assessed and applied as necessary when transfering from one probe to the other.

Having obtained percentage errors for all 4 speeds, calculate the mean percentage error: ie.
% ERROR 4 Kn + % ERROR 8 Kn + % ERROR 12 Kn + % ERROR 16 Kn
= MEAN PERCENTAGE ERROR.

Using BR 268(3B) EM LOG MANUAL PLATE 19, obtain sensitivity figure in uV/Knot from setting on Rod Sensitivity Pot (RV 13) ie. with POT set to position 7.00 sensitivity figure from graph reads 407 uV/Knot.

Example. If Mean Percentage Error = +14.73%.

$\frac{407 \times 14.73}{100}$ = 59.95 uV/Knot. This figure is subtracted from 407uV/Knot as a positive percentage error and requires the Log sensitivity to be reduced. 407 - 59.95 = 347.05
This corresponds to RV 13 setting of 2.20
This setting will adjust for overall rod sensitivity.
Now each linear pot requires adjustment as follows.

For example : 4 Knot % error = +19.5%.
8 Knot % error = +11.1%.
12 Knot % error = +13.6%.

4 KNOT POT No. 1: ADJUSTMENT — 4 Knot % error - mean percentage error.

19.5% - 14.73% = + 4.77%
ie. 4.77% of 4 Knots which equals $\frac{4.77 \times 4}{100}$ = +0.19

8 KNOT POT No. 2: ADJUSTMENT — 8 Knot % error - mean percentage error.

11.1% - 14.73% = - 3.63%
ie. -3.63% of 8 Knots which equals $\frac{-3.63 \times 8}{100}$ = -0.3

12 KNOT POT No. 3: ADJUSTMENT — 12 Knot % error - mean percentage error.

13.6% - 14.73 = - 1.13%
ie. -1.13% of 12 Knots which equals $\frac{-1.13 \times 12}{100}$ = -0.14

What this achieves is to adjust sensitivity to mean the errors and then make a small adjustment to each of the linear pots for the difference between each individual error and the mean.

METHOD 1



## E.M. LOG CALIBRATION

| RUN No. | TIME OF RUN (STOPWATCH) | DISTANCE SERVO | | DISTANCE RUN | AVERAGE LOG SPEED | CALCULATED TRUE SPEED | % LOG ERROR |
|---|---|---|---|---|---|---|---|
| | | START RUN | STOP RUN | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | | | | | | |
| 16 | | | | | | | |

RUN 1.

$$V1 = \frac{3600 \times d1}{t}$$

$$L1 = \frac{3600 \times d2}{t}$$

RUN 2.

$$V2 = \frac{3600 \times d1}{t}$$

$$L2 = \frac{3600 \times d2}{t}$$

WHERE:

d1 = MEASURED MILE.

d2 = DISTANCE TRAVELLED

t = TIME OF RUN

V1 = TRUE SPEED

L1 = LOG SPEED

$$\% \text{ ERROR} = \frac{100}{1}\left(\frac{V1 + V2}{L1 + L2} - 1\right)$$

CHECK SHAFT RPM

SM SURFACED - 22 TURNS/KNOT

SM DIVED - 25 TURNS/KNOT

METHOD 1

## E.M. LOG CALIBRATION

Examples of calculations taken during E.M. Log calibration.

$$V1 = \frac{3600(\text{sec}) \times d1(\text{Measured Mile})}{t(\text{sec})}$$

$$L1 = \frac{3600(\text{sec}) \times d2(\text{Distance Travelled})}{t(\text{sec})}$$

$$\% \text{ ERROR} = \frac{100}{1}\left(\frac{V1 + V2}{L1 + L2}\right) - 1$$

EXAMPLE: 8 KNOT RUN.

RUN 1

$$V1 = \frac{3600 \times 1.388}{569} = 8.78$$

$$L1 = \frac{3600 \times 1.21}{569} = 7.65$$

RUN 2

$$V2 = \frac{3600 \times 1.388}{716} = 6.97$$

$$L2 = \frac{3600 \times 1.53}{716} = 7.69$$

% ERROR.

$$= \frac{8.78 + 6.97}{7.65 + 7.69} = (1.02 - 1) \times 100$$

= 2% ERROR

METHOD 2

| RUN No. | TIME OF RUN (STOPWATCH) | SHAFT RPM | | DISTANCE RUN BY LOG (MILES) | LOG SPEED | MINI RANGER DISTANCE RUN | MINI RANGER TRUE SPEED | LOG ERROR |
|---|---|---|---|---|---|---|---|---|
| | | PORT | STBD | | | | | |
| | | | | | | | | |
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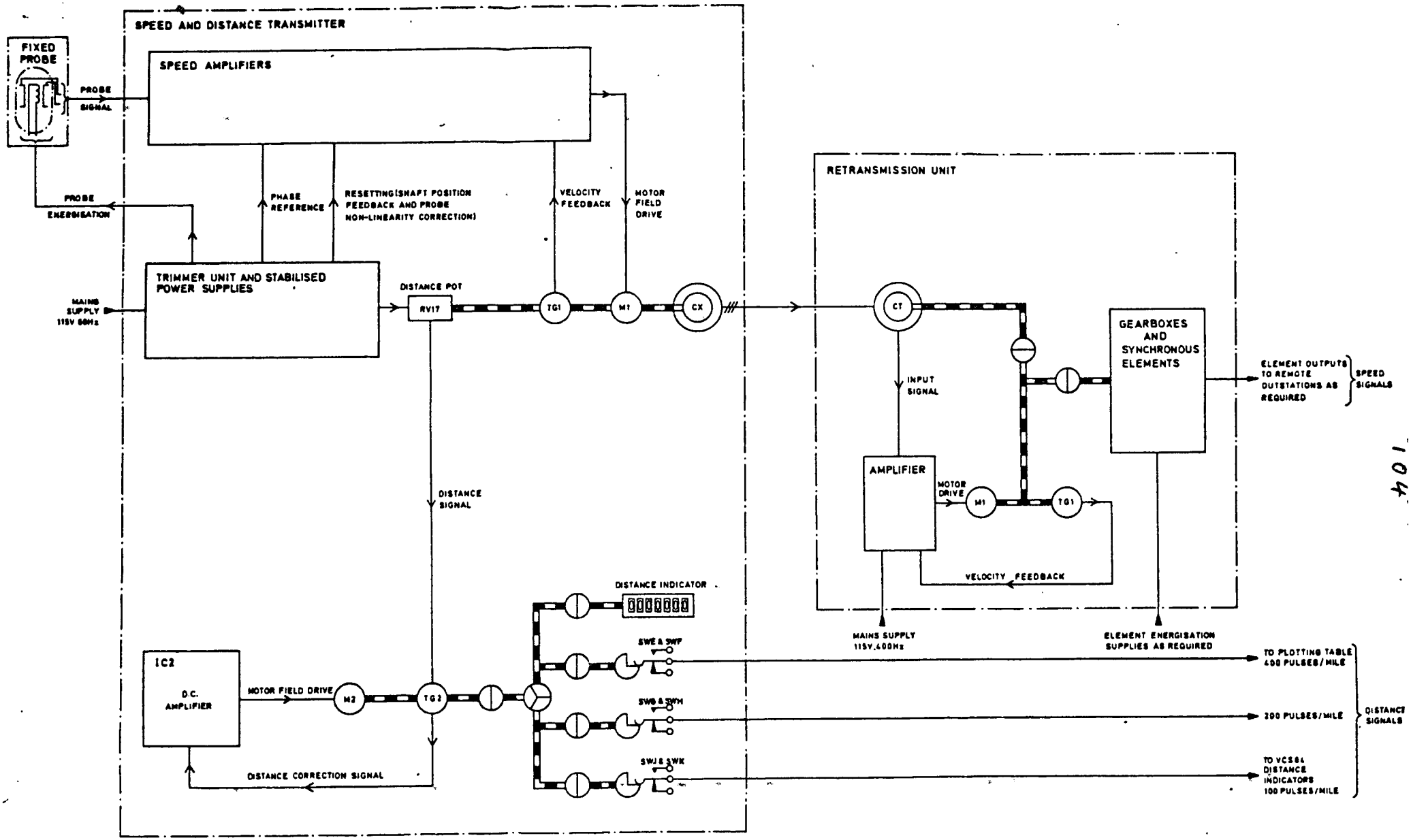
CALIBRATION RUNS ARE TO BE CARRIED OUT IN BOTH DIRECTIONS




SYSTEM - BLOCK DIAGRAM

FIG 3.2

## ARTIFICIAL HORIZON PERISCOPE SEXTANT

The AHPS is supplied from ships 115 volts 400 cycles and is housed in the ocular box on the attack periscope. The system requires two operators.

The altitude of the sun or star is measured by moving the periscope prism in 2 degree steps to bring the sun or star into the field of view. This measures altitude within 2 degrees. By providing the artificial horizon, the precise altitude within the 2 degrees can be measured.

The two pairs of lines for the artificial horizon are reflected from a mirror mounted on the same gymbal as a control gyro which is used to control and stabilise the mirror movement. The gyro is self stabilising in azimuth along the line of sight, but to line up the lines around the sun or star the gyro is processed in tilt, thus angling the mirror by applying torques to the gyro.

A pendulum is used as the reference for the horizon. It is attached to the vertical (mirror) gymbal enabling tilt of the mirror to be measured against the pendulum by means of a synchro and a transistorised amplifier to drive a servo in the averager unit.

Due to movement in a sea-way the pendulum is subjected to errors, but these errors can be assumed to average out to zero over a period of two minutes.

While the observer keeps the lines around the star, the averager can be wound up then run for two minutes during which it will add one sixtieth of the instantaneous pendulum angle every two seconds. Thus at the end of two minutes its dial will register the average pendulum angle over the period.

Instantaneous angle is also indicated.

### STABILISATION IN AZIMUTH

Any misalignment of the gyro offsets the rotor of a synchro transmitter whose stator is secured to the vertical ring. The resultant signal is fed to a transistorised amplifier, which controls a torque motor secured to the horizontal gymbal. The rotor of this motor exerts a torque about the vertical gymbal causing the gyro to precess in azimuth, in a direction to reduce the misalignment.

### OBSERVERS CONTROLS

a. Power ON/OFF Supply Switch.
b. Servo ON/OFF Switch.
c. Elevate and Depress buttons.
d. Fast/Slow Switch.
e. Drift Control.

The observer's elevate and depress buttons directly control the operation of the observer's torque motor, which is secured to the vertical ring and exerts a torque about the gyro axis. This causes the gyro to precess in tilt and, as it is secured to the vertical ring, to carry the ring and reflecting mirror with it. The buttons control the motor to elevate or depress the ring as required.

e. Switch to 'SLOW' and use observer's button and drift control to place heavenly body between the lines. (Inner lines for stars and outer lines for the sun).

f. Press the start push and continue to track the star for two minutes while the averager runs. Note the deck watch time on starting the averager. After two minutes read off the averager dial.

INDEX ERROR

An Index Error of about five degrees is built into the system, and this error should be checked before going on patrol.

One method is to take a series of observations of the natural horizon.

a. Set the prism to zero and take an observation with the horizon between the two artificial horizon lines.

b. Add the Dip correction to the averager reading and this gives Index Error.

c. Should be taken on the beam with a clear horizon.

CALCULATING THE SIGHT

a. Write down Deck Watch time.

b. Add half averager time.

c. Apply Deck Watch Error to find GMT.

TRUE ALTITUDE

a. Note Step number.

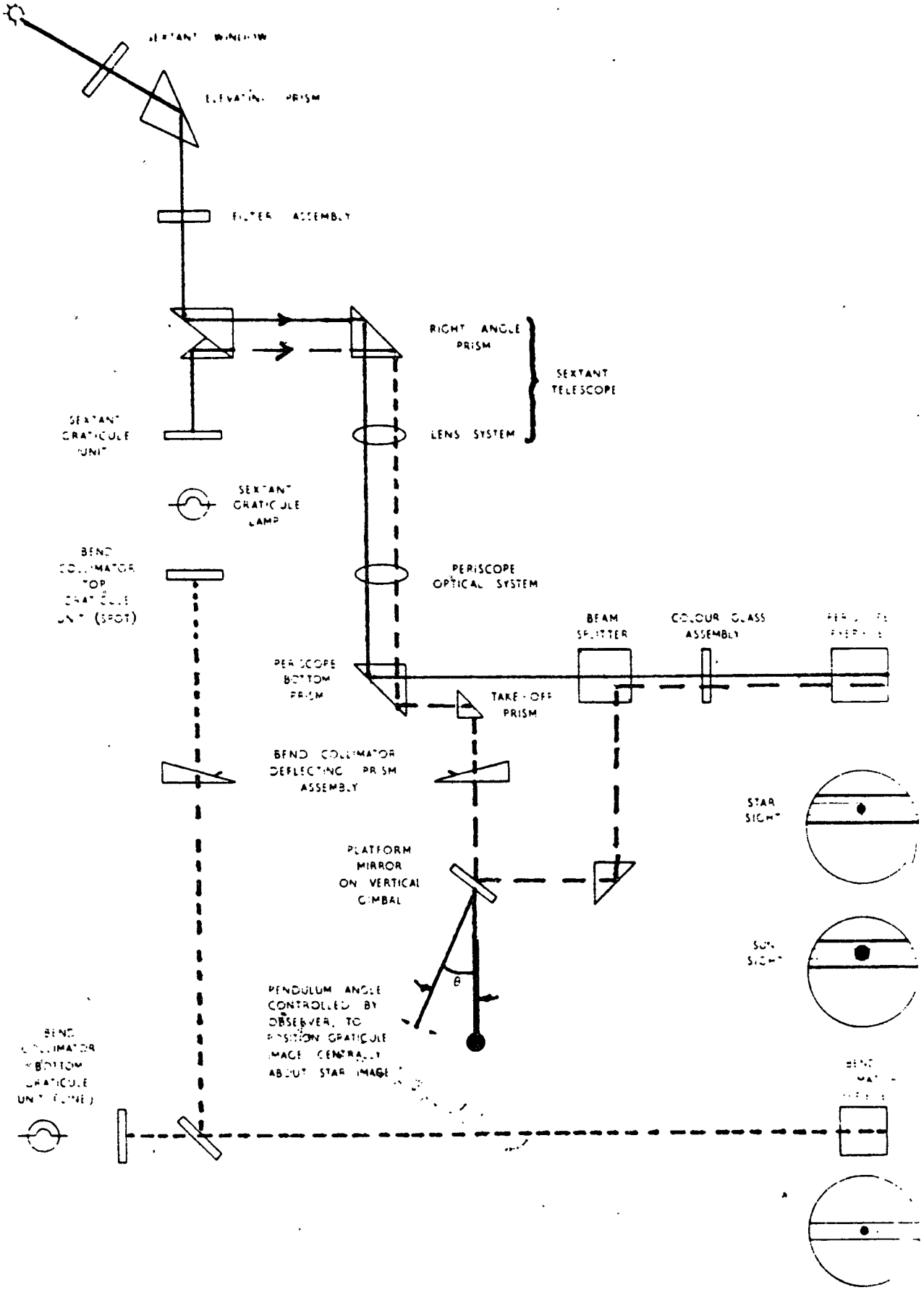
b. Write down corresponding value from calibration sheet.

c. Add averager reading.

d. If a sonar observation, use refraction correction as for a star or planet. There is no semi-diameter correction.

e. Subtract the Index Error.

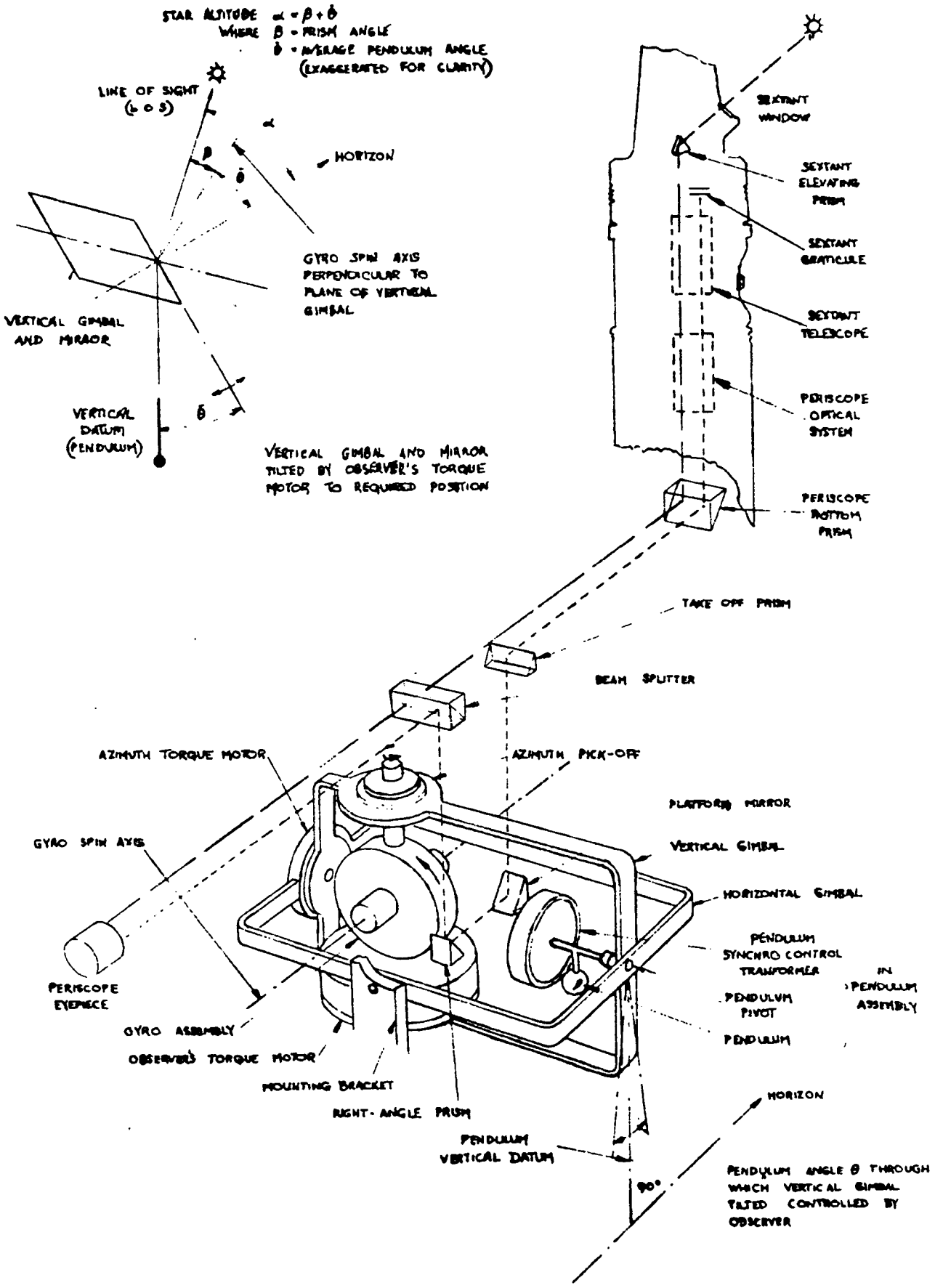
f. Apply all normal corrections except Dip.




# SEXTANT OPTICAL SYSTEM -

## FUNCTIONAL DIAGRAM

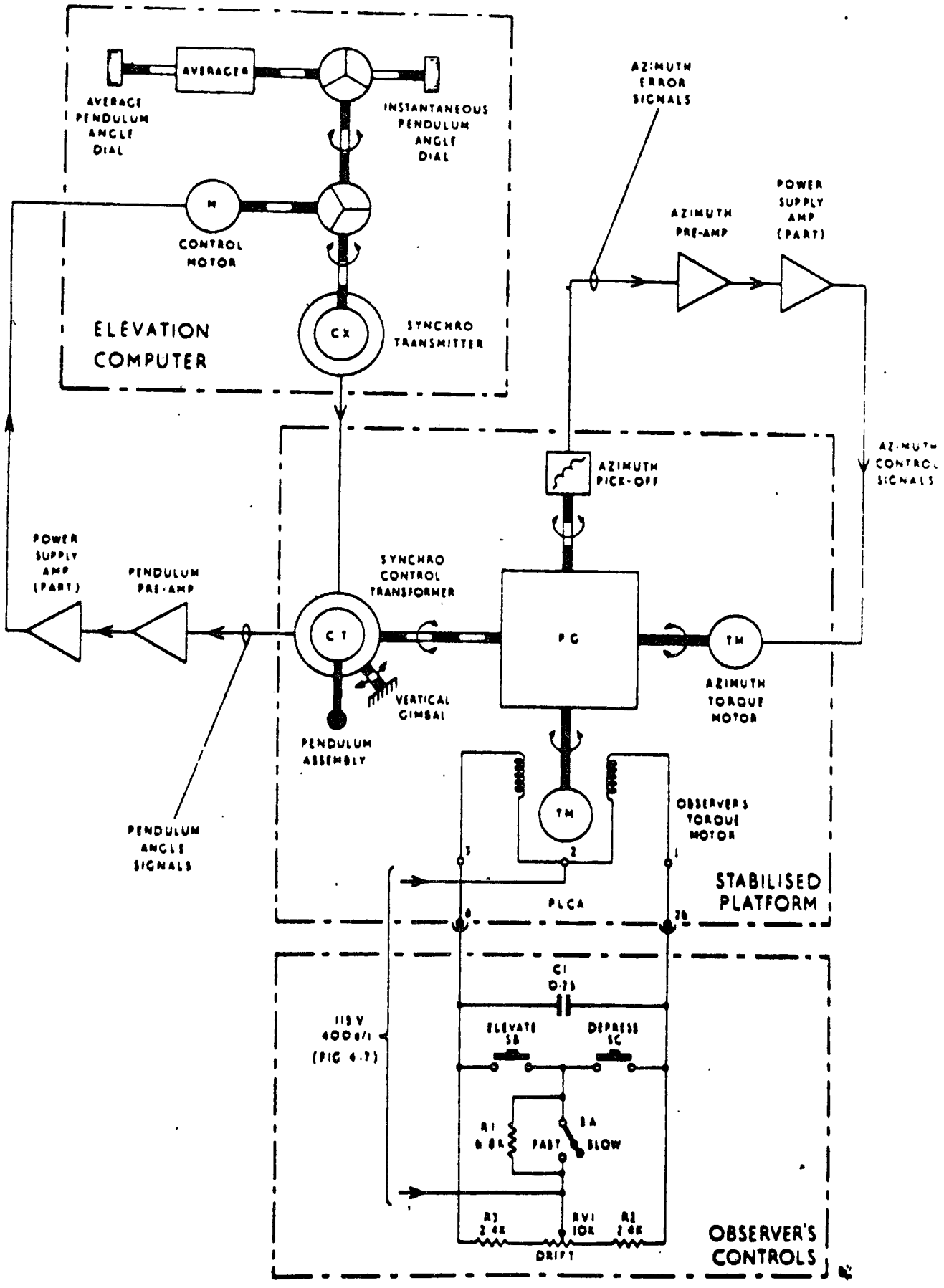
FIG 2 2




# STABILISED PLATFORM

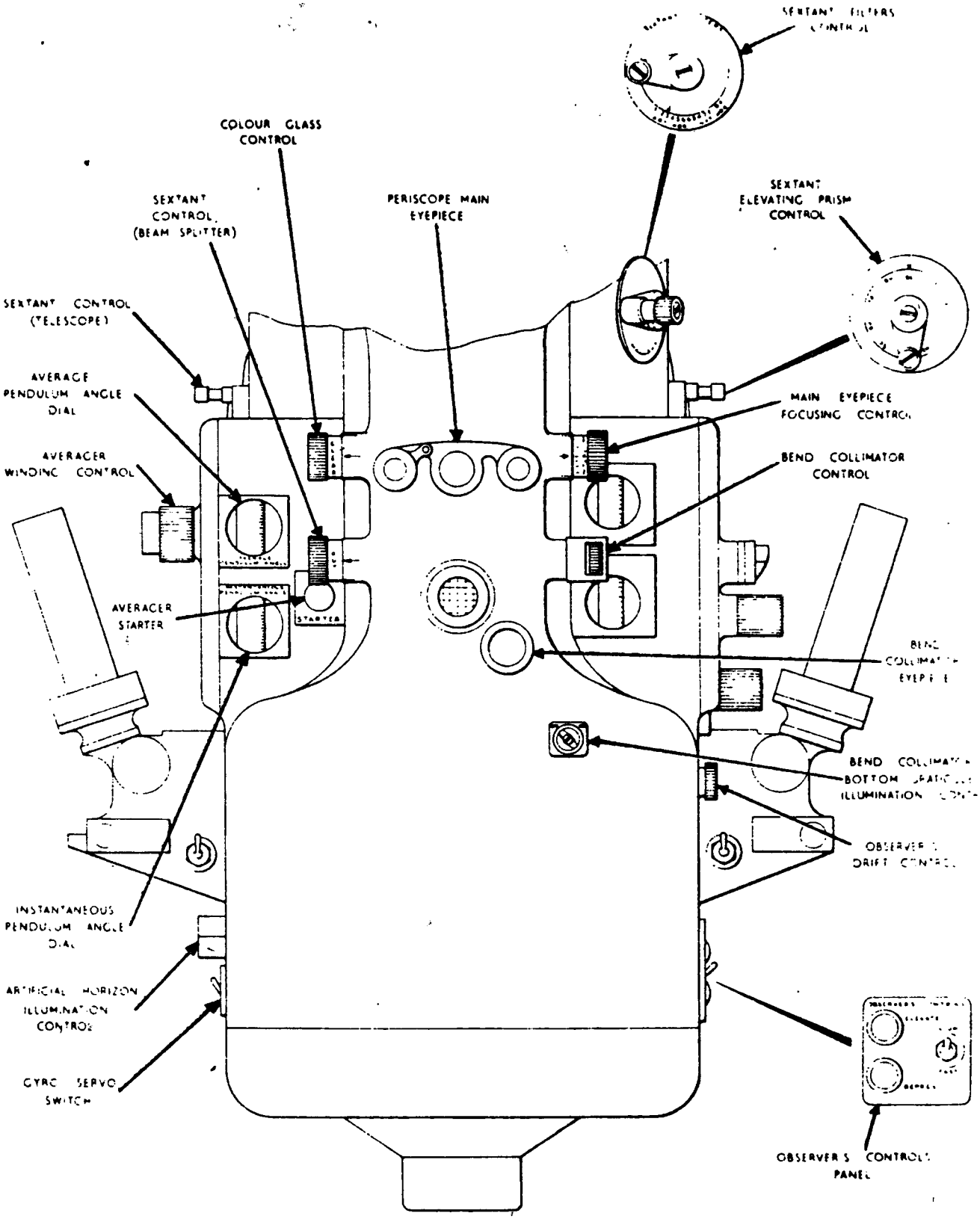
FUNCTIONAL DIAGRAM

FIG 23



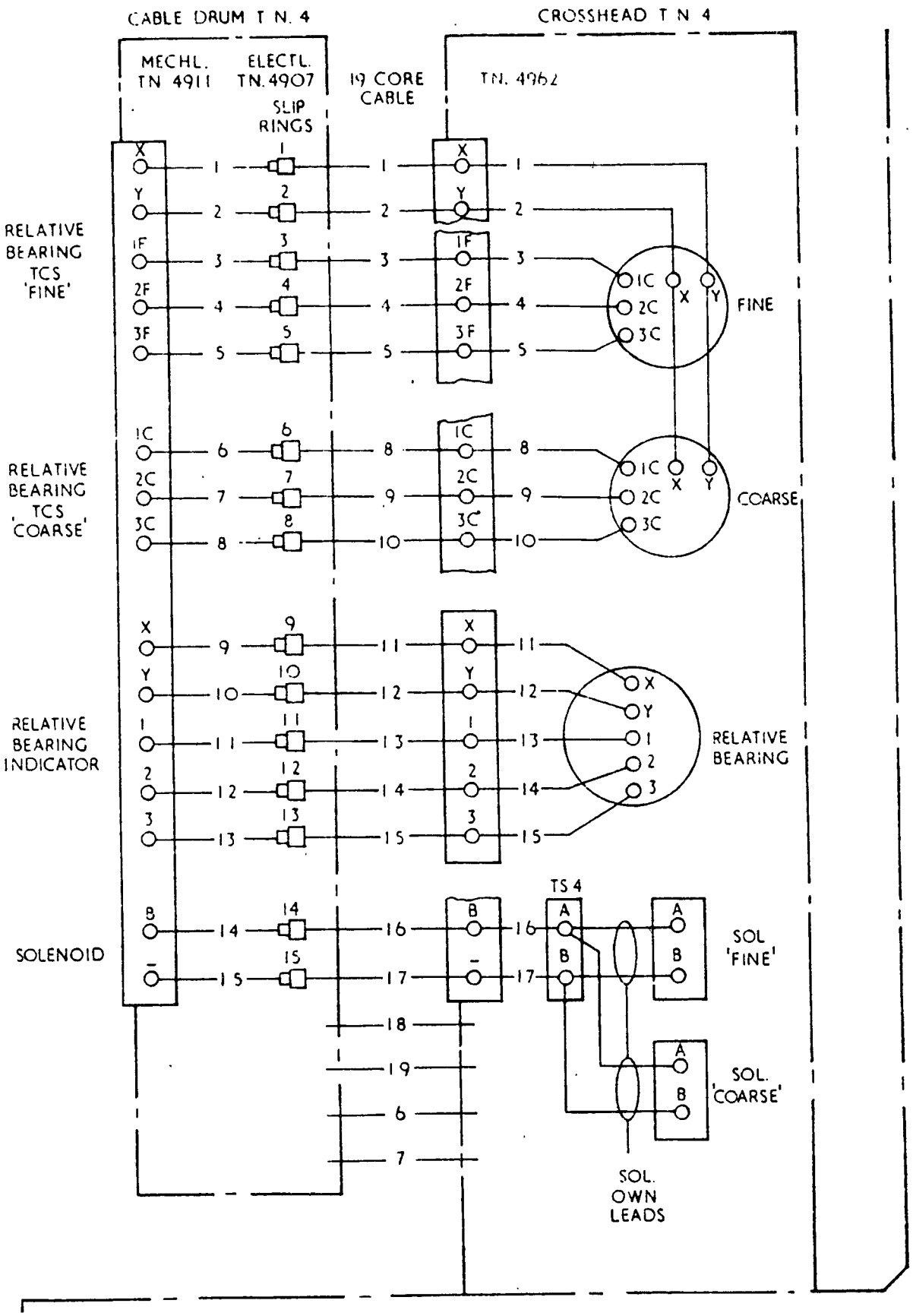

# GYRO CONTROL SYSTEMS
## FUNCTIONAL DIAGRAM

FIG. 4 4




# CONTROLS & INDICATORS

FIG 2 4


CABLE DRUM T N. 4
CROSSHEAD T N 4
MECHL. TN 4911
ELECTL. TN.4907
SLIP RINGS
19 CORE CABLE
TN. 4962
RELATIVE BEARING TCS 'FINE'
RELATIVE BEARING TCS 'COARSE'
RELATIVE BEARING INDICATOR
SOLENOID
FINE
COARSE
RELATIVE BEARING
TS 4
SOL 'FINE'
SOL. 'COARSE'
SOL. OWN LEADS

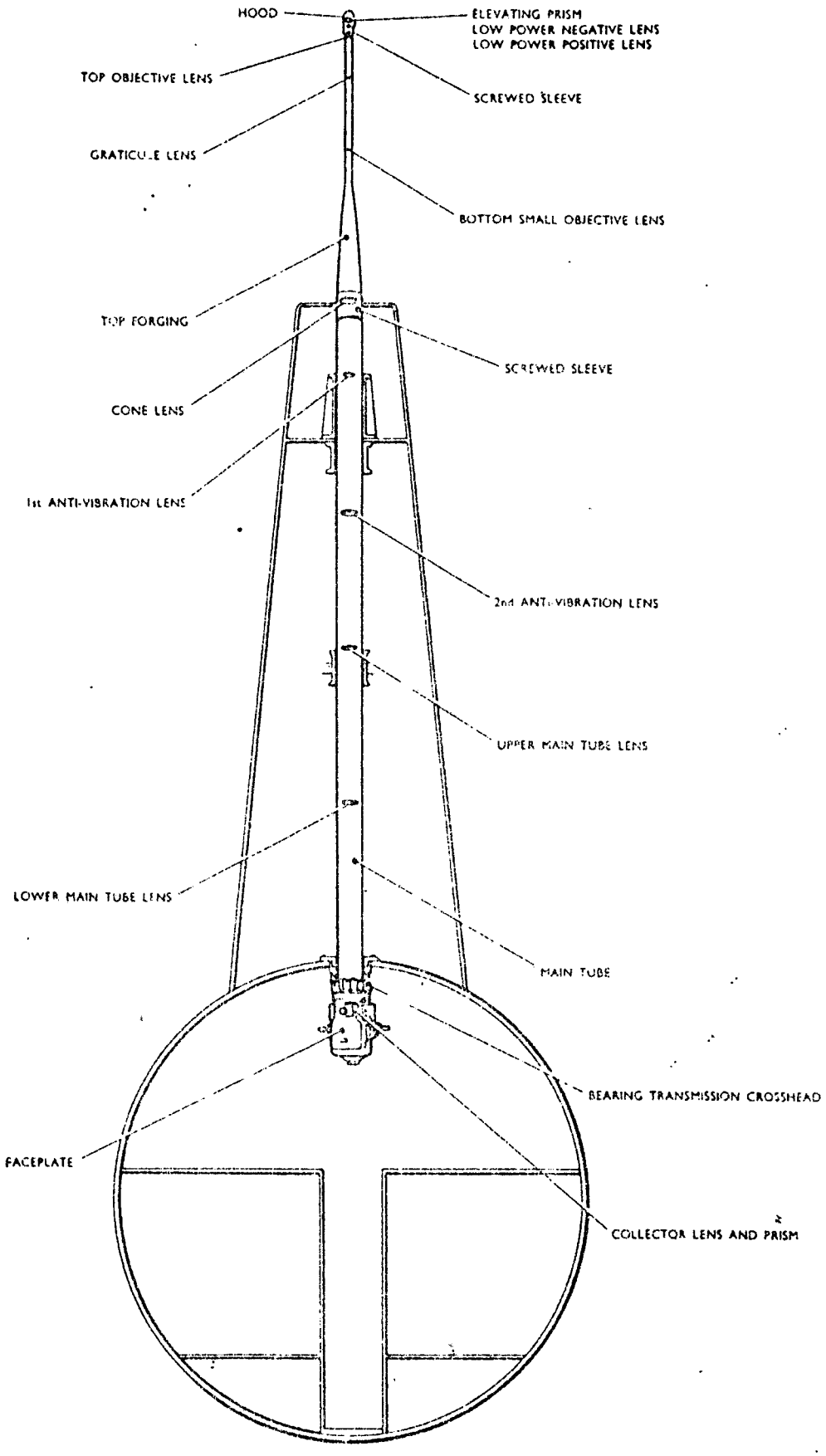
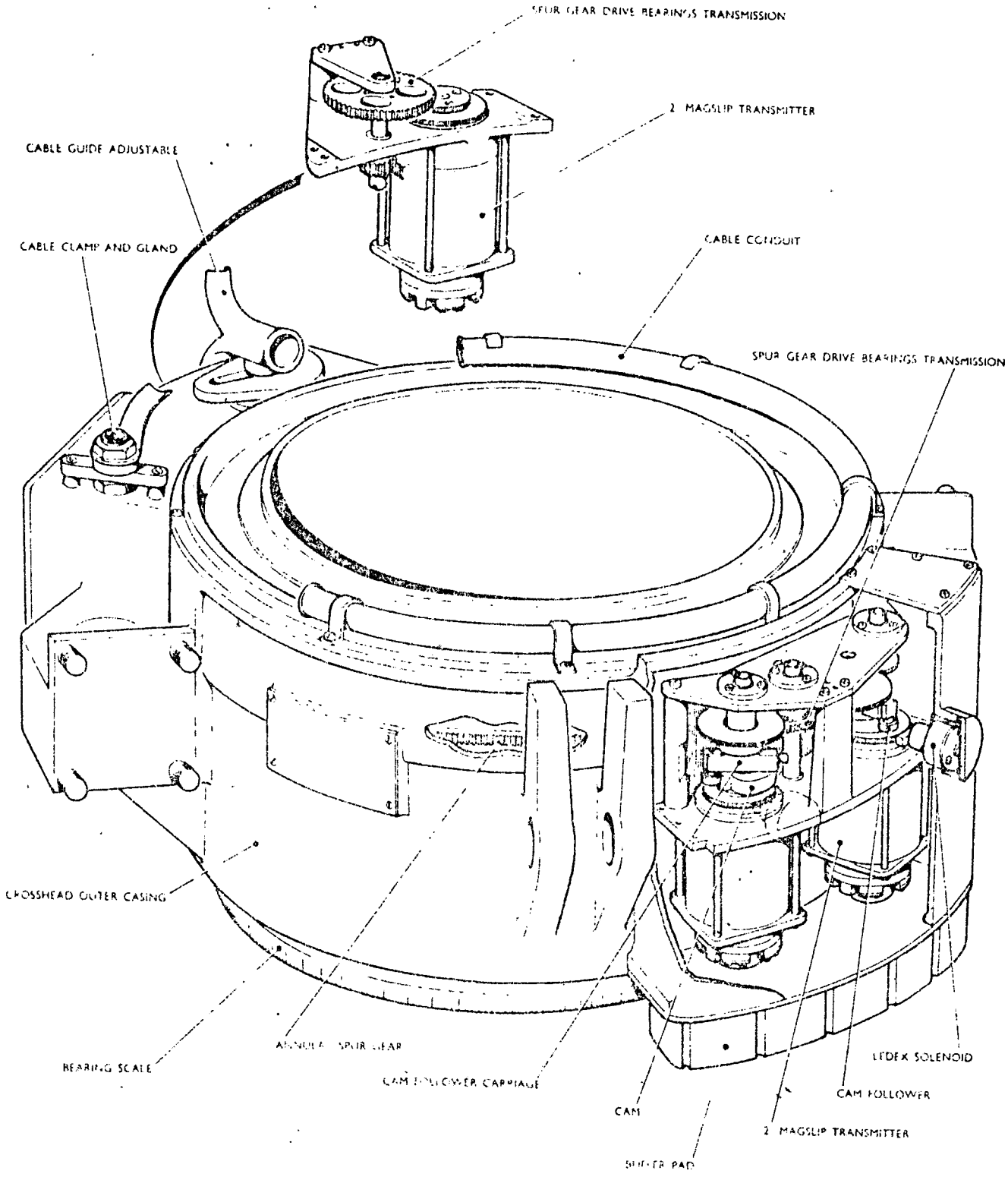
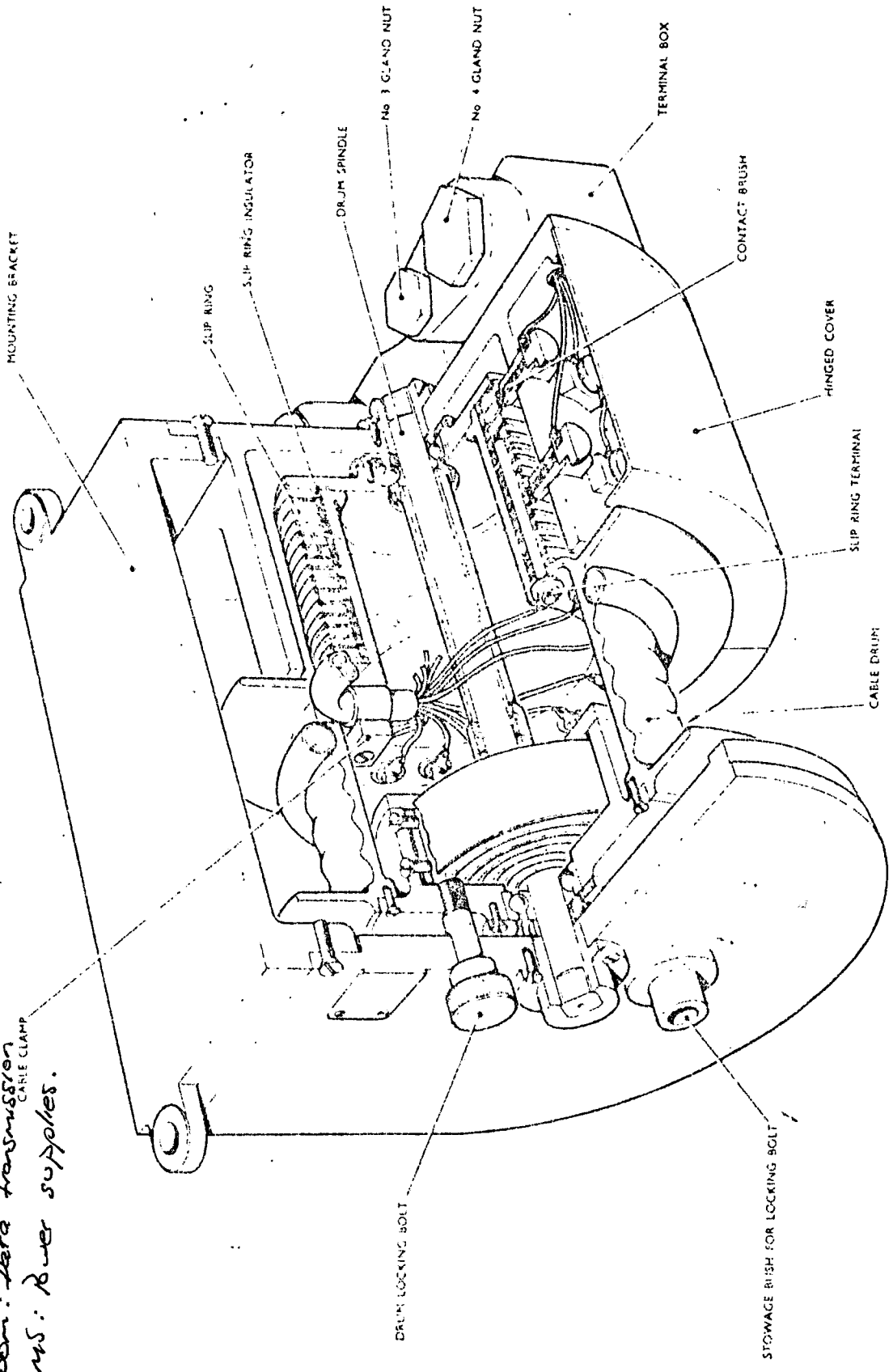



FIG. 5.1 ATTACK PERISCOPE—GENERAL ARRANGEMENT




BEARING TRANSMISSION CROSSHEAD; TN4

FIG. 6.2




ATTACK PERISCOPE—CABLE STOWAGE UNIT, TN4

FIG. 6.1



Each periscope has two.
Control Room: Data transmission
Aft: Power supplies.

# GYRO COMPASS THEORY

## A FREE GYROSCOPE

If a heavy wheel rotating at high speed is supported in rings that provide three mutually perpendicular axis, then the wheel becomes a free gyroscope having greedom to move about:

a. The Spin Axis.

b. The Horizontal Axis.

c. The Vertical Axis.

## A GYRO COMPASS

This is a free gyroscope to which has been added certain control devices which make it seek and continuously indicate true north. The gyro compass depends upon four natural phenomena for its operation. The first two are inherent properties of the gyroscope:

(1.) Gyroscopic Inertia or Rigidity in Space.

(2.) Precession.

(3.) Earth's rotation.

(4.) Gravity.

## 1. GYROSCOPIC INERTIA OR RIGIDITY IN SPACE

Gyroscopic Inertia or Rigidity in space in that property of a gyroscope which makes it try to keep the spin axis parallel to its original position. This property is explained by Newton's Laws of Motion which state that:

"A wheel in motion will continue to move at constant speed in the same direction unless it is acted upon by an outside force".

A free gyroscope will maintain a fixed point in space regardless of how the supporting frame is tilted or turned. The factors upon which gyroscopic inertia depend are:

a. Angular velocity or speed of the wheel.

b. Weight.

c. Distribution of the mass or radius at which the weight is concentrated.

## 2. PRECESSION

Precession is that property of a gyroscope which causes the spin axis to change direction when a torque if applied to it. If a torque is applied to a spinning body about the horizontal axis, the applied torque meets with resistance and the gyro precesses or turns about the vertical axis.

If there were complete absence of friction about the precessional axis, the rate of precession would be exactly equal to the applied torque and no movement in the direction of the torque would take place.

If a force is applied at a single point on the rim of a gyro wheel, that point will not move in response to the pressure, but a point 90 deg. away in the direction of rotation will move instead.

A simple rule to remember:

"If the gyro is tilted it turns."
"If the gyro is turned it tilts."

## 3. EARTH'S ROTATIONAL EFFECT ON A FREE GYROSCOPE

### a. Vertical Earth Rate

If the gyro were placed at the North Pole with its spin axis horizontal, the observer would rotate with the earth and the gyro axis maintains a fixed direction in space. The axis would appear to drift away from its original direction on the earth's surface. Only after the earth had completed a whole

3. a. continued ...

revolution would the gyro seem to have returned to its starting position. This gives the gyro axis a rate of drift of 15 degs/hour - called "Vertical Earth Rate".

b. Horizontal Earth Rate

If the gyro were now placed at the equator with the gyro axis horizontal in an East-West direction , the axle would again maintain a fixed direction in space. But to an observer, the horizontal plane on which he were standing would start to tilt east side down. Therefore the axle of the gyro remaining fixed in space, appears to tilt east side upwards, becomes vertical after 6 hours, horizontal but with original east end pointing west after 12 hours, vertical again but upside down after 18 hours and finally horizontal again and in its original position after 24 hours. This apparent rate of tilt of gyro axis is 15 degs per hour - "Horizontal Earth Rate".

Effect of Vertical Earth Rate or Drift

Maximum at the poles, zero at equator, varies as sine of latitude.

Effect of Horizontal Earth Rate or Tilt

Maximum at the equator, zero at the poles, varies as cosine latitude at points between the poles and the equator, the gyro is affected by both the horizontal and vertical earth rates. The relative magnitude of the effects are a function of latitude.

If the north end of a gyro axis is to the east of meridian - it rises. If the north end of gyro axis is to the west of meridian - it falls. In northern latitudes the northern end will drift to the East. In southern latitudes the northern end will drift to the west.

4. GRAVITY

It is the rotation of the gyro with respect to the earth which makes it possible to apply the force of gravity to convert a free gyroscope into a gyro compass.

The Free Gyroscope as a Compass

To convert a free gyroscope into a gyro compass the gyro spin axis must be controlled to seek and maintain true North.

4. continued ...

a. Vertical Earth Rate Compensation

A free gyroscope has an easterly rate of drift due to VER of 15 sine lat deg/hr. To compensate for this drift the gyro must be precessed in azimuth at a rate equal and opposite to VER. In the simple form of gyro compass this precession in azimuth is produced by a weight (latitude Rider Weight) exerting a torque about the horizontal axis. This weight, when properly adjusted for latitude will cancel out apparant drift in azimuth.

b. A North Seeking Gyro

When a level gyro is allowed to drift from the meridian it immediately begins to tilt due to HER. But if a weight is mounted on the gyro case making it top heavy - ie: pendulous, it causes a torque about the horizontal axis. This torque will now produce a precession about the vertical axis. By suitable choice of weight the precession can be arranged to precess the spin axis back to the meridian. At the meridian it will have no tendency to tile further, but, having tilted, it will continue to precess past the meridian. As the north end of the axle crosses the meridian the earth's rotation reduces the tilt. As the tilt becomes less the precession becomes less. Finally the axle has processed as far west of the meridian as it was east originally. As the earth continues to rotate, the weight causes the precession to take place in the opposite direction, carrying the gyro axle back across the meridian to its original position. Thus a gyro with a bail weight becomes a type of gyro compass - an undamped gyro compass.

c. A North Finding Gyro (Damped Gyro)

A compass which oscillates about the meridian is unsatisfactory. To make the compass settle on the meridian and remain there this oscillation must be damped. Damping is achieved by introducing torques round the vertical axis which produce precessions tending to reduce tilt. The weight, instead of being attached directly to the gyro casing, is pivoted independently in another ring surrounding the vertical ring. The torque developed by any tilt can then be applied to the gyro in a plane slightly offset to east of the vertical plane of the gyro. Thus a fraction of the torque can be applied about the vertical axis to give the required precession in tilt.

## FACTORS AFFECTING COMPASS ACCURACY

### Causes of Loss of Azimuth Datum - Summary

1. Vertical Earth's Rate at 15 x sine latitude deg/hr.
2. Effect of movement over earth's surface - North/South and East/West
3. Rotor speed variations.
4. Voltage variations.
5. Acceleration effects on the gimbal and control system.
6. Other constant torque effects as a result of:
   a. Mass unbalance due to manufacturing tolerances.
   b. Mass shift due to bearing wear, shock and consequent distortion of the gimbal system.
   c. Interference with trimmer weights.
   d. Temperature changes affecting expansion rates possible causing mass shift.
   e. Unequal amounts of oil in rotor bearings (where applicable).
   f. Twist in mechanical suspension arrangement of sensitive gimbal system (where applicable).
7. Stray torque effects as a result of:
   a. Magnetic linkage effect of 'E' Pick offs and Torquers (where applicable).
   b. Air movement over the gimbal system.
   c. Reaction torques due to loading the sensitive gimbals by transmitting devices or supply arrangements.
   d. Gimbal bearing friction.

### The Effect of Uncompensated Vertical Earth's Rate

For example - consider the ship in a Northern Latitude.

The effect of VER will cause the 'N' end of axis to move to the East at a rate proportional to 15 sine lat deg/hr.

Departure of the axis from the meridian will cause it to acquire a tilt rate due to HER. This will be detected by the normal gravity control resulting in precession of the axis in azimuth and tilt. Eventually the 'N' end of the spin axis would settle to the East of the meridian and be tilted up.

The amplitude of the azimuth error will be proportional to the vertical rate at that Latitude.

The compass will settle when:

VER = Precessional rate in azimuth from the gravity control.
HER = Precessional rate in tilt (Damping) from the gravity control.

Similarly, with the ship in the Southern Hemisphere, the 'N' end of the axis would settle to the West of the meridian with an azimuth error and 'N' end tilted down.

In the Admiralty gyro compass series, VER is compensated by manual adjustment of the Latitude Rider Weight. Normally this is set for a mean latitude thus decreasing the accuracy of the compass.

In the modern gyro compasses (Mk.19, 23 and Arma Brown) compensation for VER is achieved by the application of an electrical signal which permits a more accurate adjustment, and therefore compensation, to b e made.

Effect of Movement over Earth's Surface

1. Effect of Ship's North-South Speed

Movement of the ship N or S over the curved surface of the earth will cause the spin axis (because of its spacial rigidity) to acquire a tilt rate proportional to ship's North or South speed. This tilt rate will be sensed by the normal control of the compass which will precess the axis to the West or East of the meridian to a position where it can settle level but with an azimuth error - ie: to a position where the effect of HER is equal and opposite to the tilt rate due to ship's N - S speed.

It has already been explained in the Admiralty series of gyro compasses that the magnitude of this error is also dependent upon Latitude and that precession of the axis near to its final settling position is achieved by the acceleration effect felt by the mercury ballistic control. In addition compensation for this speed error is achieved by computing V cosine course x secant latitude and applying the correction to the transmission.

In the modern gyro compasses (Mk. 19, 23 and Arma Brown) an electrical signal is developed and applied to the gyro sensitive gimbal system as a torque in order to precess the axis at an equal and opposite rate to that caused by ship's N/S speed, thus maintaining the axis in the meridian.

2. Effect of Ship's E-W Speed

Ship's E-W speed will effectively vary the earth's angular rate of 15 deg/hr, and therefore the resolution of earth's rate into VER and HER will apparently add to Earth's rate and vice versa.

If the spin axis is maintained in the meridian by a modified VER compensation the modification to HER may be disregarded as its effect will be wholly about the spin axis.

Theoretical appreciation of effect of E-W Speed on VER

Let R = Radius of the earth at Equator.

Therefore Radius in the meridian plane at any point on earth's surface = R COS LAT (Dia. III).

Consider ship's Easterly speed V at equator (Dia. IV).

Ship's angular rate = $\frac{V}{R}$

As R varies as Cos Lat, Ship's angular rate anywhere on earth's surface = $\frac{R}{R \text{ Cos Lat}}$

This is the additional angular rate about the earth's spin axis.

Since rotation about the vertical axis of the gyro due to either VER or E/W speed varies as the sine of the latitude, the effect of this additional angular rate on VER must therefore vary as the sine of the latitude. Thus the effective change on VER = $\frac{V}{R \cos \text{ lat}}$ x sine lat = $\frac{V \tan \text{ lat}}{R}$.

As 'R' (earth's radius at the equator) is a constant, the expression may be written as E/W speed Tan Lat.

This effect becomes very significant in high latitudes and to achieve a greater degree of accuracy of the defined meridian, compensation must be applied. However, in the Mk.19, an electrical signal proportional to E/W speed Tan Lat is computed to apply a correction, thus achieving greater accuracy.

Effect of a Constant Torque

A constant unwanted torque applied to the sensitive gimbal system will result in a constant rate of precession of the axis in azimuth or tilt.

If the torque is about the horizontal axis, the spin axis will precess from the meridian, acquire a tilt due to HER and finally settle with a tile and an azimuth error either to the East or the West of the meridian and settle with an azimuth error but level where the axis can acquire an equal but opposite rate of tilt due to HER.

To achieve the desired compass accuracy, correction for this error must be made. In the AP.5005 series, static and dynamic balancing and adjustment of suspension for twist of the master compass may be necessary. In the Mk.23 and Mk.19 correction is achieved by the controlled effect of electrical torques which provide compensating precessions in opposition to those due to the unwanted constant torque. The method adopted in the above equipments will be dealt with when discussing the specific equipment.

Rotor Speed Variations

It is already appreciated that precessional rates are inversely proportional to rotor speed.

Variations of rotor speed outside permitted tolerances will, for given torque inputs, result in incorrect precessional rates, consequent inaccuracies in the desired datum - eg:

Consider rotor speed a definite % too high with the compass in the 'N' hemisphere. In this example VER compensation would be insufficient and axis would settle to the East of the meridian with 'N' end tilted up. (See dia. I).

In the admiralty gyro compass series, a limited control of rotor speed is provided, but in Mk.23 and Mk.14 gyro compasses there are no specific speed conrtrol arrangements other than those provided by the frequency control of ship's supply, presumably because of the higher rotor speed of these gyros (23400 rpm).

Voltage Variations

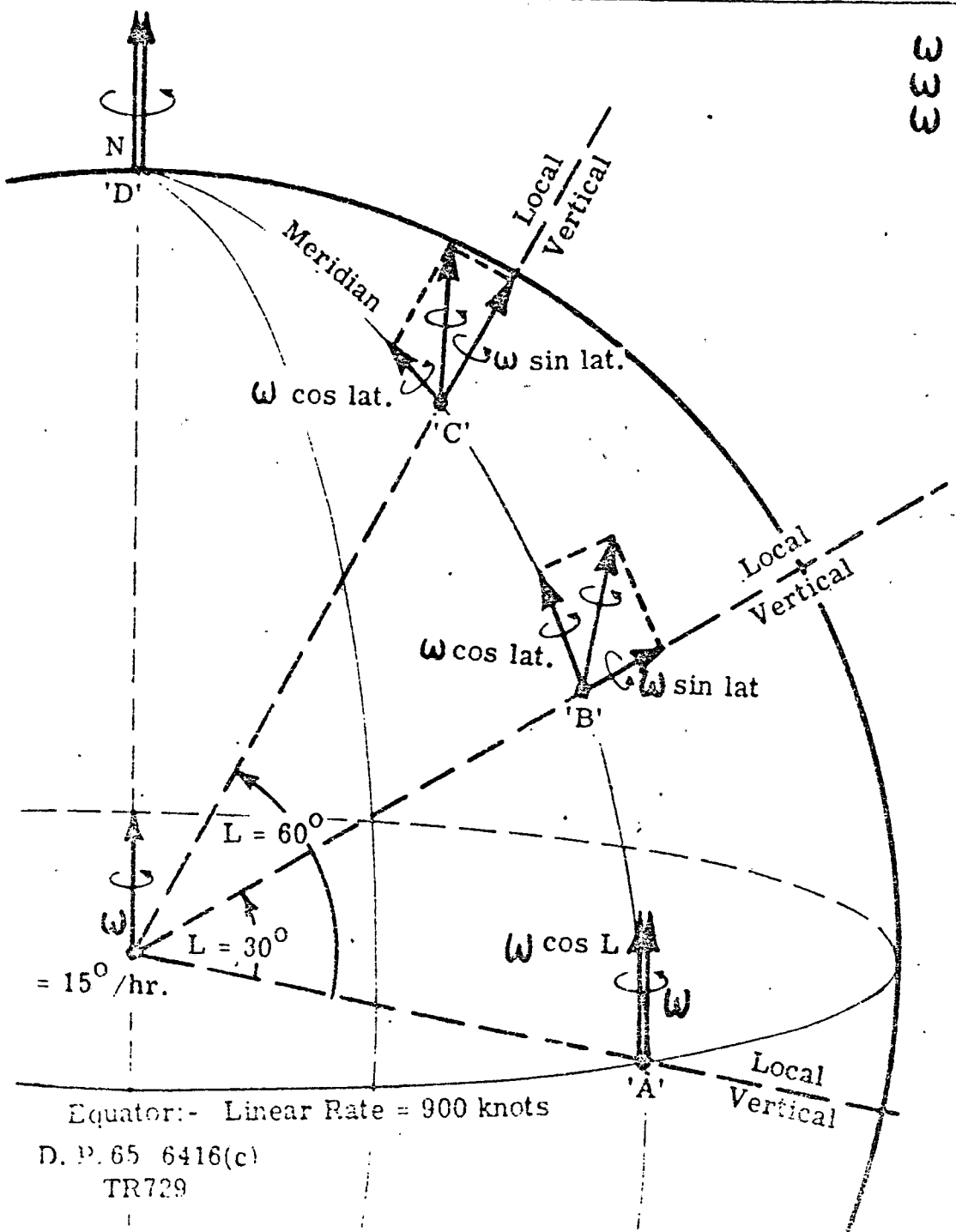
No special arrangements to compensate for line voltage variations are provided in the Admiralty range of compasses.

However, in the Mk.19 and Mk.23 compasses, because of the electronic control of the compensation techniques, line voltage regulation and voltage compensation respectively is provided.

Acceleration Effects

Because of the difference in the physical assembly of the compass sensitive gimbal systems and methods of control in the various types of gyro compasses the effect of both long and short term accelerations will be dealt with when discussing individual equipments.

# RESOLUTION OF TRUE EARTH'S RATE INTO VERTICAL AND HORIZONTAL COMPONENTS AT ANY LATITUDE




$\omega$ = true earth's rate - 15°/hr.
$\omega$ sin lat. = rotation about vertical axis
$\omega$ cos lat. = rotation about horizontal axis

Point 'A'. Latitude Zero

$\sin 0^\circ$ = zero. ∴ no rotation about vertical axis

$\cos 0^\circ = 1$ ∴ max. (15°/hr.) rotation about horizontal axis

Point 'B'. Latitude 30°

$\sin 30^\circ = 0.5$ ∴ VER = 15 x 0.5 = 7.5°/hr.

$\cos 30^\circ = 0.866$ ∴ HER = 15 x 0.866 = 12.99°/hr.

Point 'C'. Latitude 60°

$\sin 60^\circ = 0.866$ ∴ VER = 15 x 0.866 = 12.99°/hr.

$\cos 60^\circ = 0.5$ ∴ HER = 15 x 0.5 = 7.5°/hr.

Point 'D'. Latitude 90°

$\sin 90^\circ = 1$ ∴ VER = 15°/hr.

$\cos 90^\circ = 0$ ∴ HER = Zero

Summary

Vertical Earth Rate (VER) or apparent drift varies as 15 sin lat. °/hr.

Horizontal Earth Rate (HER) or apparent drift varies as 15 lat. °/hr.

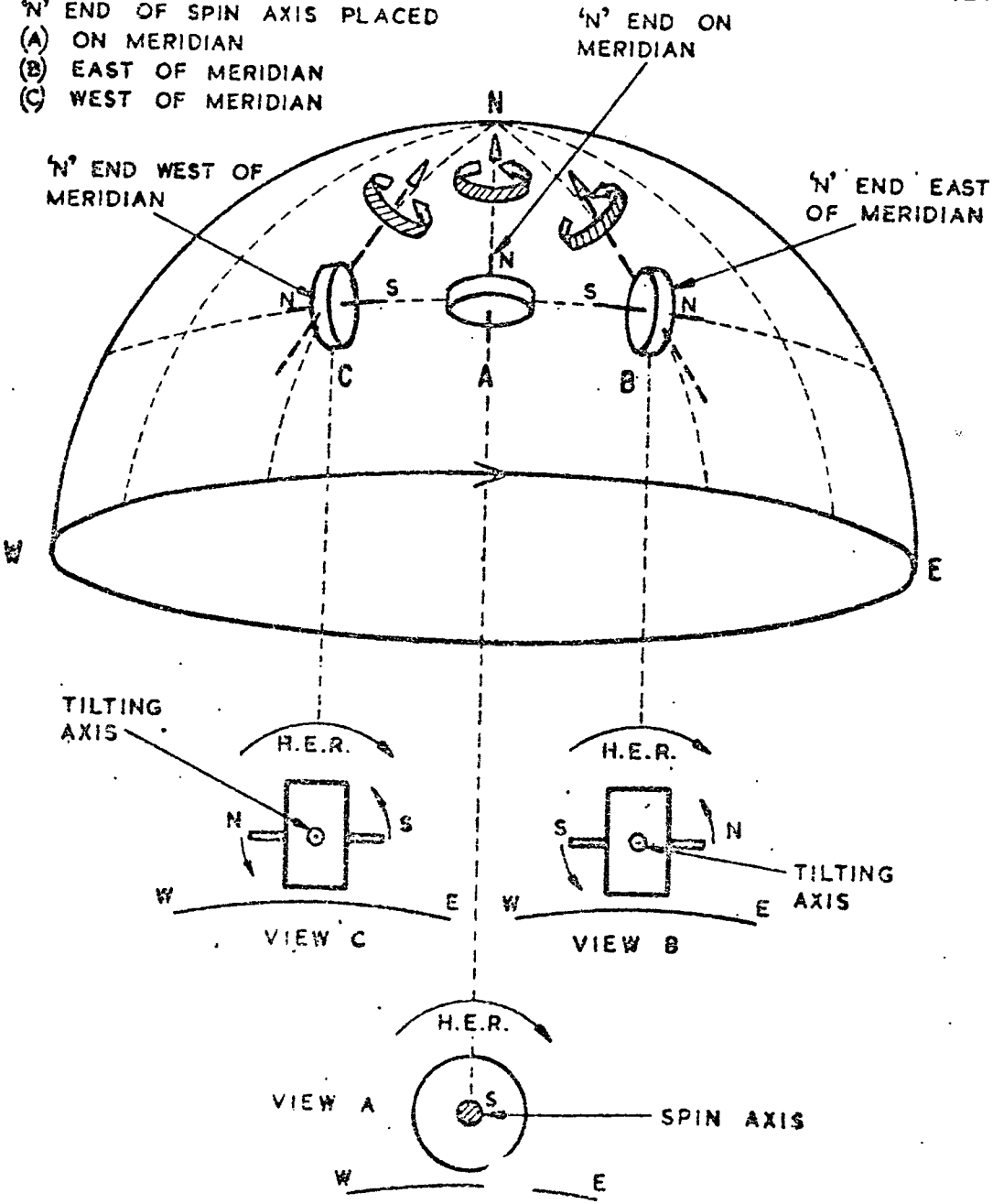
D. P. 65 6416(c)
TR729

# H.E.R. EFFECTS ON A FREE GYRO

## RESULTS IN MOVEMENT ABOUT HORIZONTAL GIMBAL AXIS I.E. APPARENT TILT

TR 712
DP 65/6381

CONSIDER
'N' END OF SPIN AXIS PLACED
(A) ON MERIDIAN
(B) EAST OF MERIDIAN
(C) WEST OF MERIDIAN




## SUMMARY

(1) IF AXIS IS ON MERIDIAN H.E.R. HAS NO EFFECT. I.E. ZERO TILT RATE.

(2) IF AXIS IS OFF TO WEST OF MERIDIAN 'N' END TILTS DOWN AND IF TO EAST 'N' END TILTS UP.

(3) TILTING RATE VARIES ACCORDING TO ANGLE OF DISPLACEMENT FROM MERIDIAN AND AS THE LATITUDE

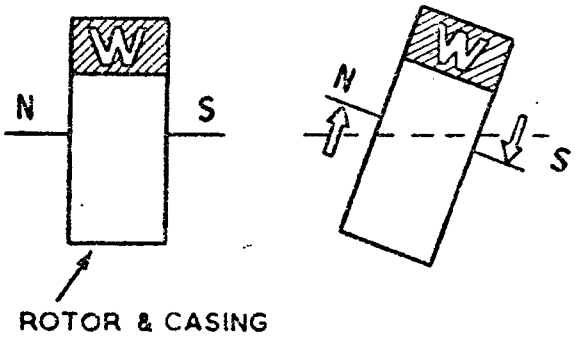
MAX. AT 0° LAT. – MIN. AT POLES.

125
-5-

| TR 708 | |
|---|---|
| DP.65/6381 | |

# BALLISTIC CONTROL—NORTH SEEKING

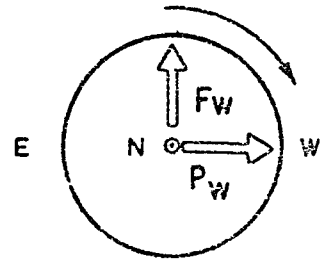
BAIL WEIGHT METHOD



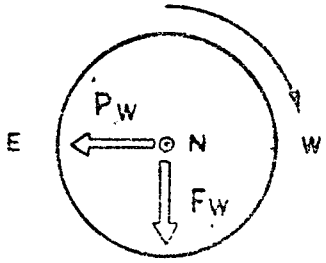

T = TILT RATE DUE TO EARTH'S ROTATION
$F_W$ = FORCE DUE TO WEIGHT
$P_W$ = PRECESSION DUE TO WEIGHT

126 -6-

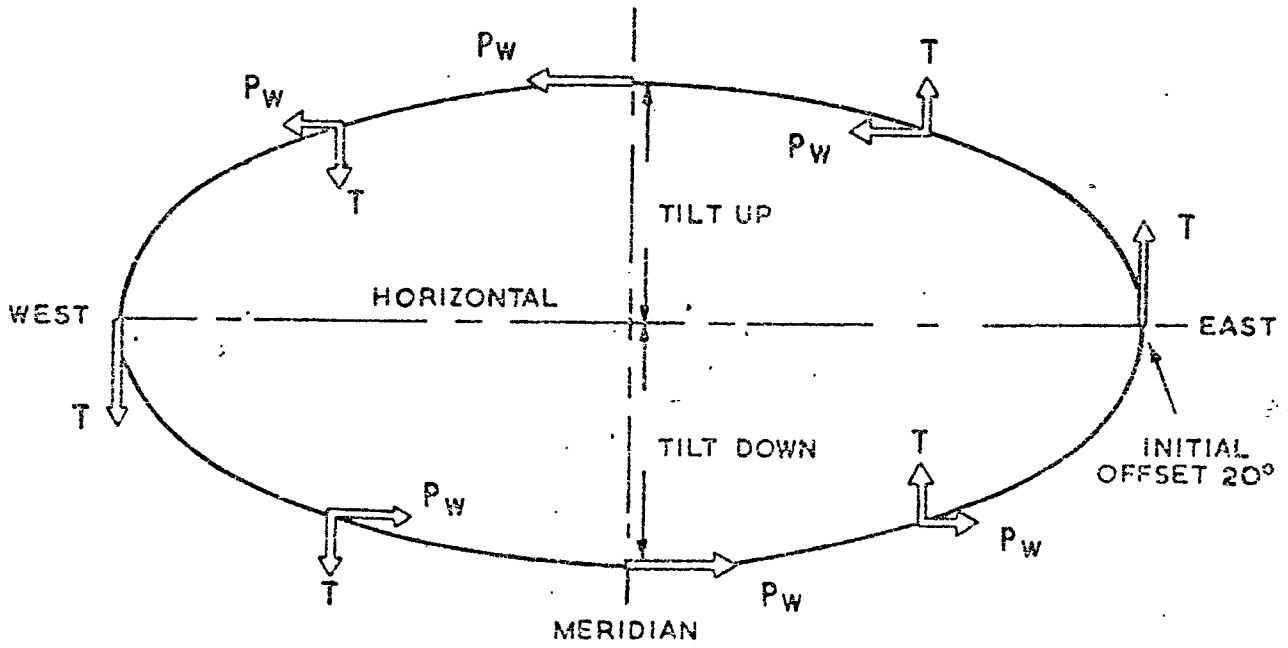
NORTH END UP




NORTH END DOWN




UNDAMPED CURVE

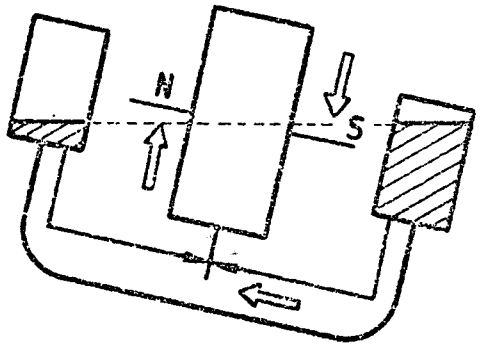


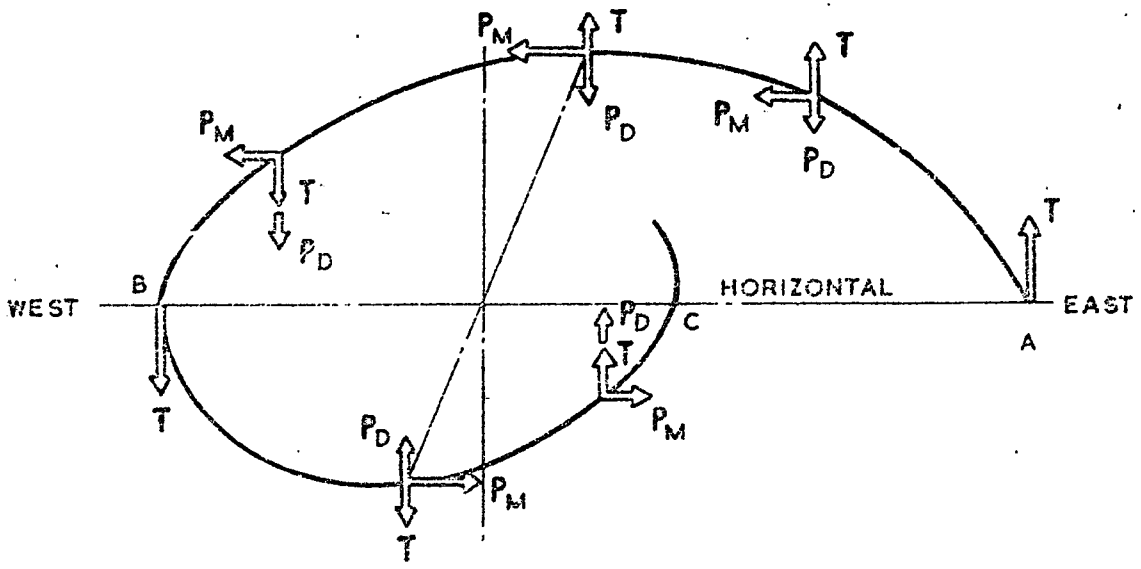

PERIOD AT LAT. 52°=84·4 MINS

TR 709
DP 65/6381

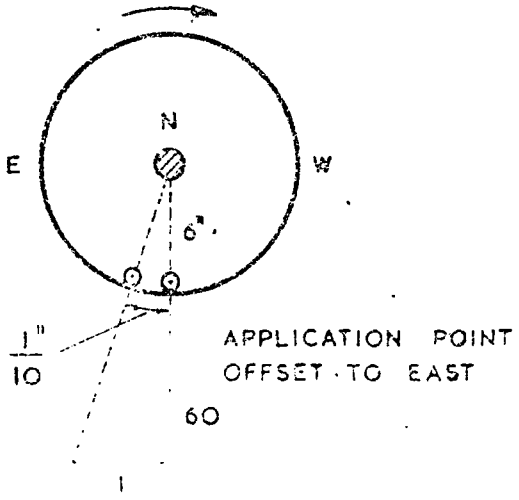
# BALLISTIC DAMPING-NORTH FINDING

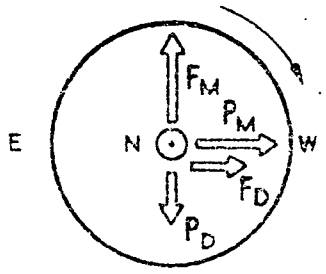
$F_M$ — FORCE DUE TO MERCURY DISPLACEMENT
$P_M$ — PRECESSION DUE TO MERCURY DISPLACEMENT
$T$ — TILT RATE DUE TO EARTH'S ROTATION
$F_D$ — FORCE DUE TO DAMPING
$P_D$ — PRECESSION DUE TO DAMPING



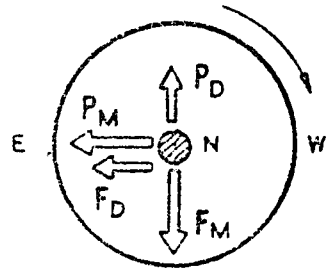




ADMIRALTY COMPASS
PERIOD 87·5 MINS. 55% DAMPED
AT LAT. 52°




'N' END UP




'N' END DOWN

# MARK 23 MOD. LI. GYROCOMPASS

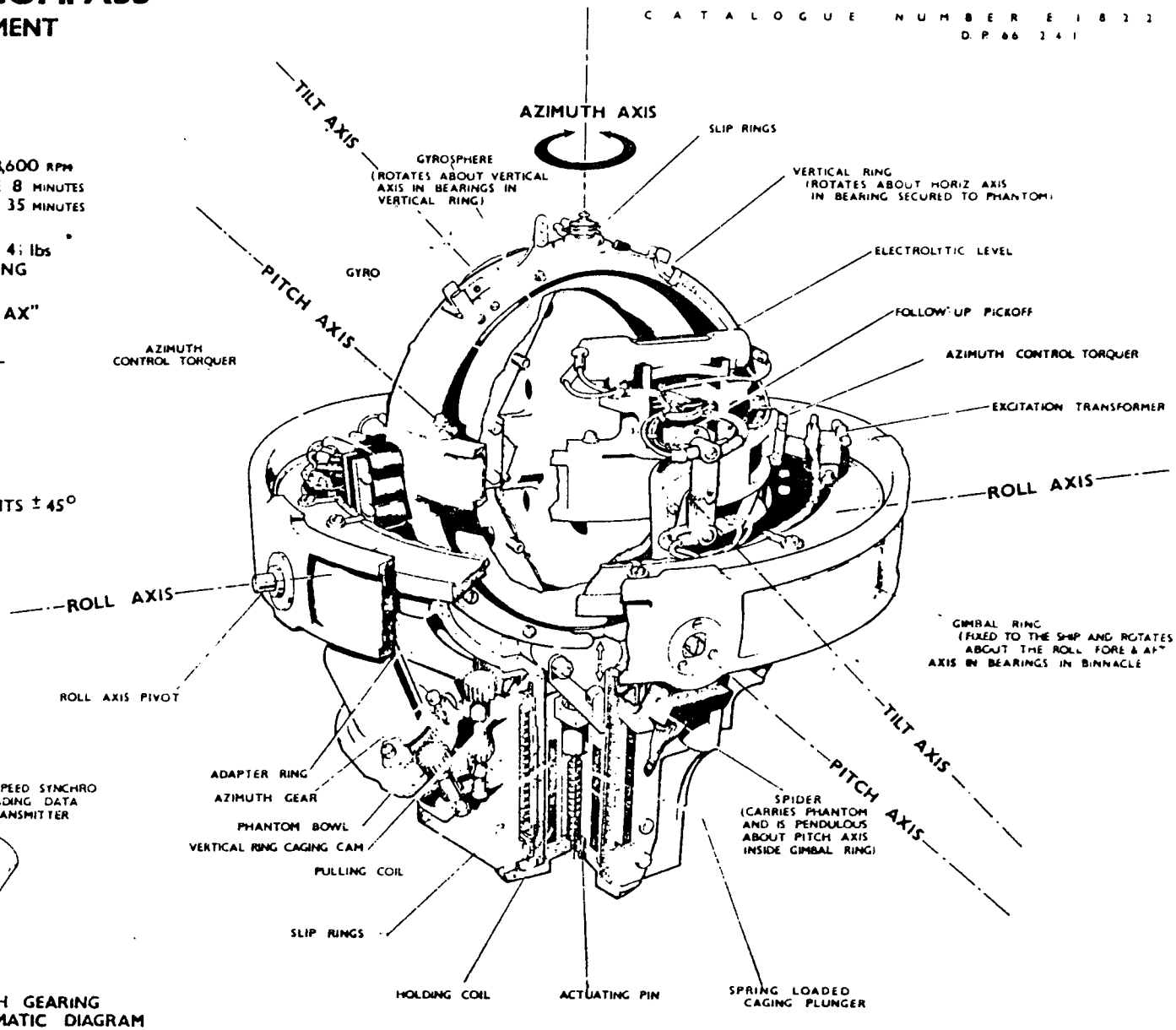
## DETAILS OF MASTER ELEMENT

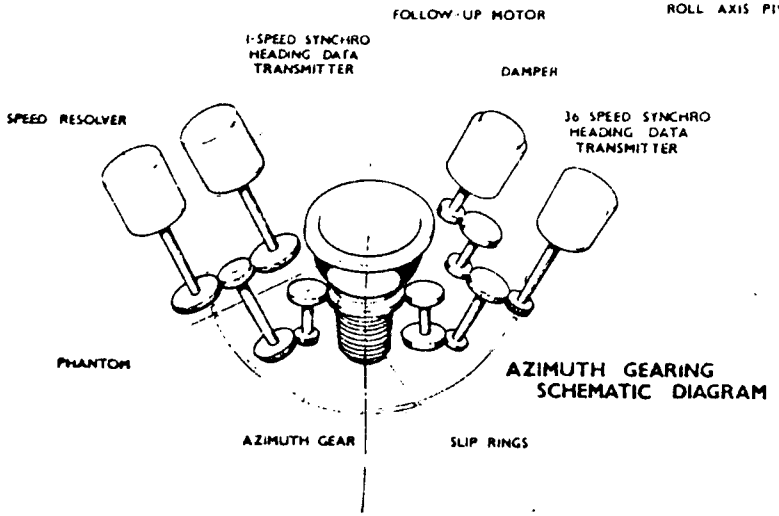
( U N C L A S S I F I E D )

C A T A L O G U E  N U M B E R  E 1 8 2 2
D. P. 66 2 4 1

### MASTER UNIT DATA

| | |
|---|---|
| GYRO | 115 VOLT, 400 CYCLES, 3 PHASE SPEED 23,600 RPM<br>STARTING CURRENT - 1 AMP RUN UP TIME 8 MINUTES<br>RUNNING CURRENT - 0·1 AMP COAST TIME 35 MINUTES |
| GYROSPHERE | 6½ INCHES DIAMETER WEIGHT 4½ lbs<br>GYROSPHERE AND VERTICAL RING TILT LIMITS ± 65°<br>OIL - SHELL "DIALA - OIL - AX" |
| DRIFT RATE | MAXIMUM ACCEPTABLE OVERALL VALUE - 0·5°/HOUR |
| FOLLOW-UP | MAXIMUM RATE 100°/SECOND<br>ALARM CONTACTS CLOSE AT ± 6° MISALIGNMENT |
| SUPPORT GIMBAL RING | PITCH AND ROLL LIMITS ± 45° |




AZIMUTH GEARING SCHEMATIC DIAGRAM

128

# PHYSICAL BUILD UP OF GYROSPHERE

| TR 2301 | |
|---|---|
| DP. 75/727 | |

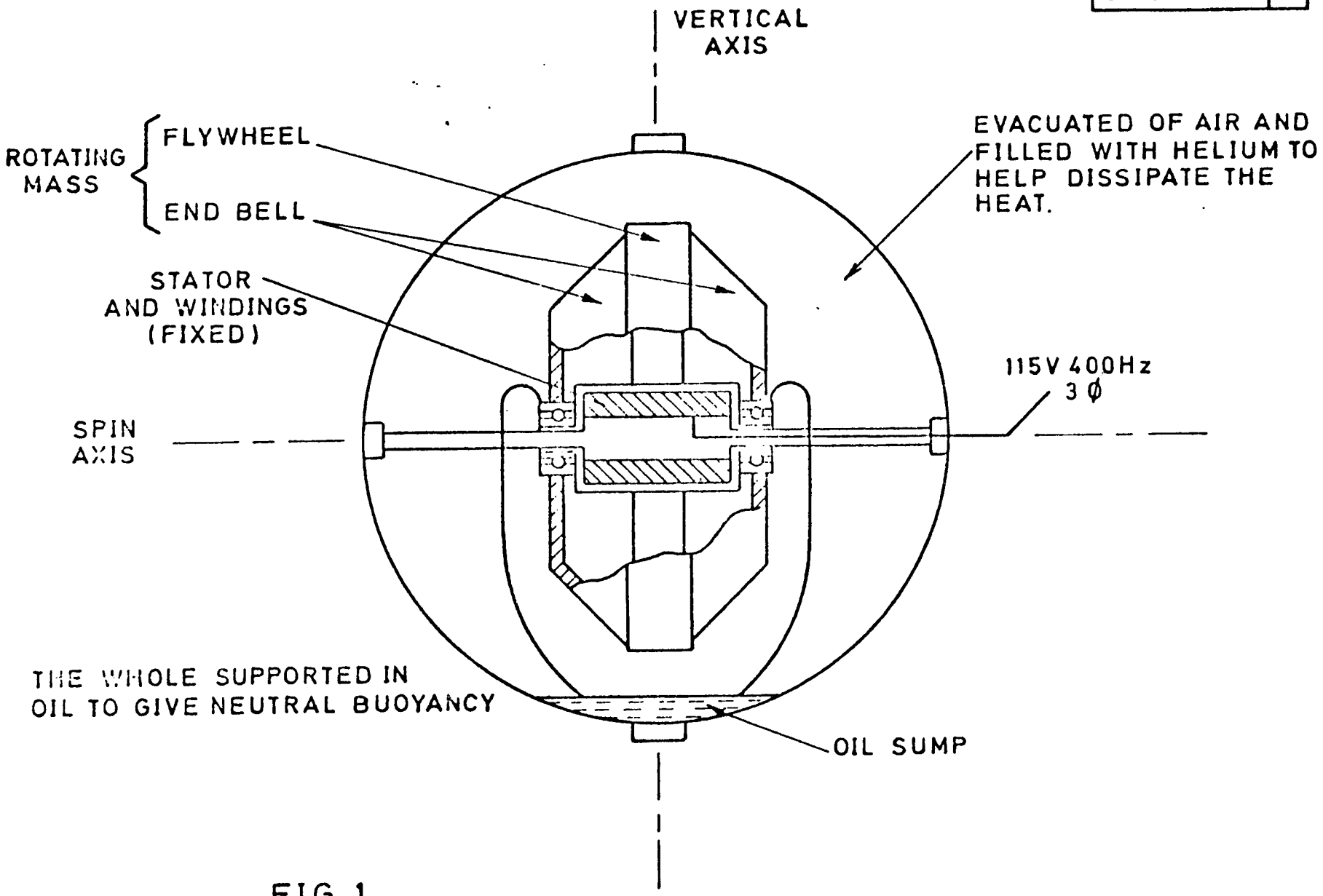

VERTICAL AXIS
ROTATING MASS
FLYWHEEL
END BELL
STATOR AND WINDINGS (FIXED)
EVACUATED OF AIR AND FILLED WITH HELIUM TO HELP DISSIPATE THE HEAT.
115V 400Hz 3 ϕ
SPIN AXIS
THE WHOLE SUPPORTED IN OIL TO GIVE NEUTRAL BUOYANCY
OIL SUMP

FIG. 1

# MARK 23 GYRO COMPASS (BRITISH MOD. LI)

## BR 1742

### Introduction

This gyro compass uses an electronic control system with transistorised amplifiers to make it seek and continuously indicate True North. As in previous gyro compasses the force of gravity combined with tilt of the gyro rotor as a consequence of earth's rotation, are used as the controlling factors. The compass supplies accurate heading data by synchro transmission of 10 degree and 360 degree sector value, and can be used as a gyro compass up to 75 degree latitude and as a directional gyro in higher latitudes.

It is capable of an accuracy as follows:

| | |
|---|---|
| Static | - 0.2 degree |
| Light sea conditions | - 0.5 degree |
| Moderate sea conditions | - 1.0 degree |
| Rough sea conditions | - 2.0 degrees |

Normally, the compass requires to be started 4 hours before proceeding to sea.

### Supplies required

1. 115 volt 400 hertz 3 phase - For main power
2. 115 volt 400 hertz 1 phase - For synchro transmissions
3. 24 volt d.c. - For alarm system and 'M' type transmissions

### System Components:

1. Master Gyro Unit - This consists of a shock mounted oil filled binnacle supporting the compass element which is gimballed within the binnacle with a freedom of ± 45 degree movement about the roll and pitch axes.

2. Control Cabinet - This unit contains all the controls, amplifiers, power supplies and networks necessary for the operation of the compass system.

3. Speed Unit - Contains the necessary components to produce an electrical signal proportional to ship's speed from either an input from the ship's log or by manual setting.

4. Alarm Control Unit - This is used to initiate a main alarm relay circuit in the event of 115 V 400 Hz 3 phase line failure, Follow-up failure, Voltage Compensator failure or internal 28 V and 160 V failure.

5. Power Distribution Panel - This unit contains power switching arrangements, a 115 V 400 Hz 1 phase alarm relay and a main alarm relay which controls the 24 V d.c. operated alarm system.

NORMAL
AN/WSN-2 : fed from ships 205V 400hz. 3 Phase supply.
MK 23 : fed from the MK4 Static Power Inverter, supplied by the C.P. ring main.

ALTERNATIVE
AN/WSN-2 : No alternative.
MK 23 : fed from ships 205V 400Hz. 3 Phase supply.

Transmission System

The Gyro compass transmits Coarse (1:1) and Fine (36:1) heading data to retransmission units and a Synchro Tape Repeater.

1. THE MASTER GYRO UNIT - PHYSICAL BUILD UP

~~Consists of three basic parts~~

(i.) Gyrosphere and Vertical ring on which is mounted the Level detector.

(ii.) The Phantom or Azimuth Follow Up and the Adaptor ring carrying the torquers and pick off devices.

(iii.) The Spider, in which the phantom turns, is suspended in an outer gimbal ring suitably pivoted to provide isolation from Ship's pitch and roll.

a. The Gyrosphere

This is the 'N' seeking part of the gyro compass and derives its name from the fact that the gyro rotor is mounted inside a spherical enclosure which is partially filled with helium to promote heat transfer. The direction of rotation of the rotor is clockwise viewed from the 'S' end. The sphere is immersed in oil at neutral buoyancy and flotation of the gyro in this manner reduces pivot friction, provides protection from shock, and minimises acceleration effects due to the fact that the gyro is non-pendulous.

b. Sensitive Gimbals and Phantom

The gyrosphere is pivoted about the vertical axis within the vertical ring. The azimuth freedom of the sphere with respect to the vertical ring, is limited by two flat springs, to ± 10 degrees. A follow up failure alarm switch fitted on the vertical ring is actuated by a striker on the gyrosphere at ± 6 degrees of misalignment. The vertical ring, consisting of two sections, is pivoted about the horizontal axis in an adaptor ring secured to the phantom so that gyrosphere and vertical ring tilt together. Stops limit the rotation of the vertical

ring about the horizontal axis to ± 65 degrees. Caging cams are fitted to the lower part of the vertical ring which allow caging of the vertical ring and gyrosphere when non-operational.

The phantom supporting the vertical ring and gyrosphere is free to rotate in azimuth within the spider, and is made pendulous by the method adapted of supporting the spider within the binnacle.

c. The spider supporting the phantom is pivoted in a gimbal ring about the pitch axis and the gimbal ring is pivoted about the fore and aft or roll axis within the binnacle.

d. Summary of Freedom movements of gyro assembly

(i). Gyrosphere can move in azimuth with respect to vertical ring and phantom.

(ii). Gyrosphere and vertical ring together can tilt about a horizontal axis with respect to the phantom.

(iii) Phantom can turn in azimuth with respect to the spider.

(iv) Spider and Gyro assembly supported to give relative freedom from ship's movements of Pitch and Roll.

2. CONTROL CABINET

CONTROL SYSTEM

Introduction

The requirements of the system are:

(i). To detect movements of the spin axis from the N/S meridian by measurement of spin axis tilt.

(ii) To precess the spin axis in azimuth into the meridian and to the level condition within the required period and damping % tolerances, and providing a follow up system to maintain phantom in correct azimuth alignment.

(iii) To compensate for V.E.R. N/S speed and voltage fluctuations.

(iv) To provide a ready means of detecting and correcting for any permanent mass unbalance or constant torque.

a. Gravity Reference System Figs 2 and 3

(i) Electrolytic Level

This is attached to the vertical ring in such a manner that it is parallel to the gyro spin axis. It produces a signal proportional to the magnitude of tilt of the spin axis and a directional sense according to the direction of tilt. Its sensitivity is 135 mV/min of tilt, it has a time constant of 180 secs with a linear response up to ± 10 min of tilt. The response of the level is reduced by the viscosity of the electrolyte in order to damp out the acceleration effects due to pitch, roll, and speed and course alterations to a limited degree.

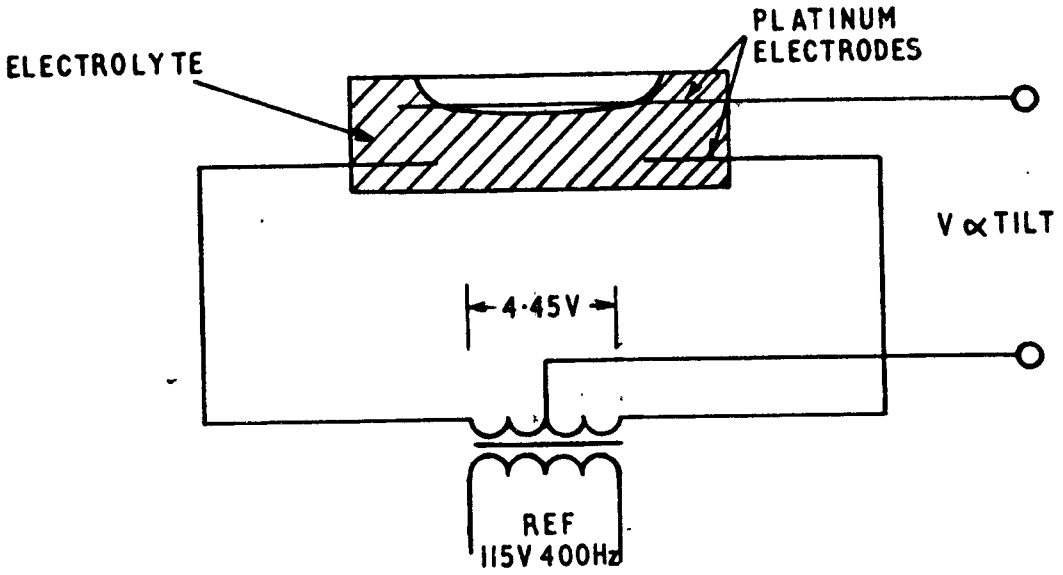



Fig 2

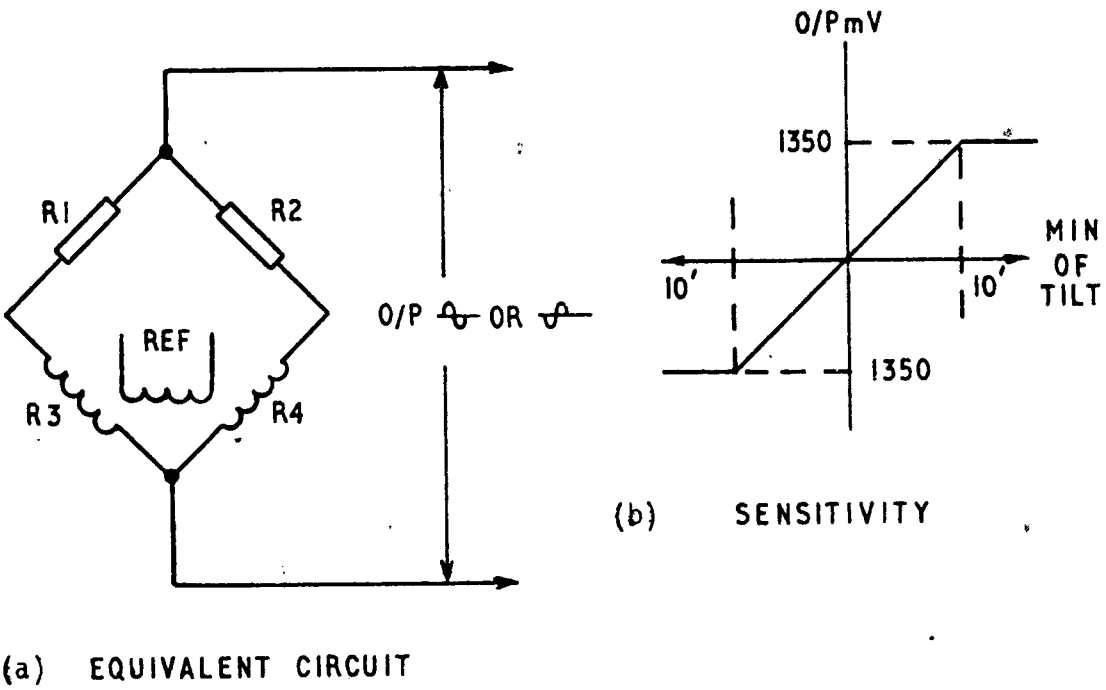



Fig 3

11. Tilt Signal Amplifier is required to amplify the tilt signal before it is applied to the azimuth and levelling control systems. It consists of a 4 stage transistorised voltage amplifier which provides the damping and period signals, and a phase sensitive demodulator circuit whose output provides a signal for a tilt meter indicator to give visual indication of tilt of the spin axis.

To provide the two compass periods and the different percentages of damping required in the SETTLE and NORMAL modes of operation, adjustable negative feedback technique is employed to modify amplifier gain. This

6.

provides the compass with a 30 minute period and 90% damping in the SETTLE mode, and an approximate 90 minute period with approximately 65% damping in the NORMAL mode of operation.

The two signal outputs (Meridian Control and Damping) are the basic signals required to control the axis to seek and find North. However, it is necessary to apply certain compensation signals to counteract the effects of V.E.R., Ship's N/S speed and mass unbalance, all of which would cause the axis to be in error outside the permitted limits of accuracy. These compensations will be dealt with later.

Meridian or Azimuth Control System

The meridian control signal output from the tilt signal amplifier, suitably scaled to give period control, is applied to a mixer network to which is also added compensating voltages for V.E.R. and balance correction. The composite output signal voltage is amplified and applied to a pair of azimuth torquers on the gimbal assembly, which produce a torque or couple about the horizontal axis of the gyro causing precession of the spin axis in azimuth.

Latitude Switch

In order to obtain satisfactory compass periods in both high and low latitudes, a latitude switch in the compass control panel will give a compass a 90 min. period at either of two latitude regions, ie 45° and 65°. The switch position adopted is the one nearest to the local latitude and to give the compass the same period at both latitudes, a change in the magnitude of the meridian control signal must be made. The compass period will vary proportionally at other latitudes but accuracy is not affected.

[redacted]

The damping signal output from the tilt signal amplifier suitably scaled to give damping percentage control is applied to a mixer network to which is added a compensating voltage for N/S speed effect. The composite signal is amplified and applied to the Levelling torquer which applies the necessary torque about the vertical axis to progressively reduce the tilt of the spin axis.

i. [redacted]

The purpose of the follow up system is to drive the phantom in azimuth so that the vertical ring is continuously aligned with the gyrosphere, and to position the synchro data transmitters and speed resolver. The system is a closed loop servo in which a 'pick off' device between vertical ring and gyrosphere provides an error signal proportional to the misalignment between them.

The error signal is amplified by a hybrid network and F.U. amplifier. The amplified signal is applied to the azimuth servomotor to drive the phantom and hence the vertical ring to null the error signal. The function of the hybrid network as well as to preamplify the error signal is to stabilise the follow-up servo loop by providing acceleration feedback.

Fig 10

Also included in the follow up system is Slewing Control. Operation of the Manual Azimuth Switch marked c.w. and c.c.w. with an OFF position, will control the follow up servomotor to slew the sensitive element to the ship's head as close as possible enabling the compass to settle in a minimum time when starting.

The input signal to the azimuth follow up amplifier and follow up motor for SLEWING is only provided when the operations switch is in the CAGE position.

It will be appreciated that although it is possible to slew with the gyro up to speed, the practice is not recommended, since the effect of the torques on the gyro will cause oscillations in tilt of the spider assembly about the roll and pitch axes. Slew rate is one azimuth in 15-30 seconds.

e. Compensations and Techniques Employed

i. Voltage Compensator Figs 5 and 7

The voltage compensator produces the necessary stabilised excitation voltages to the three compensating controls, Latitude, Speed and Balance Correction.

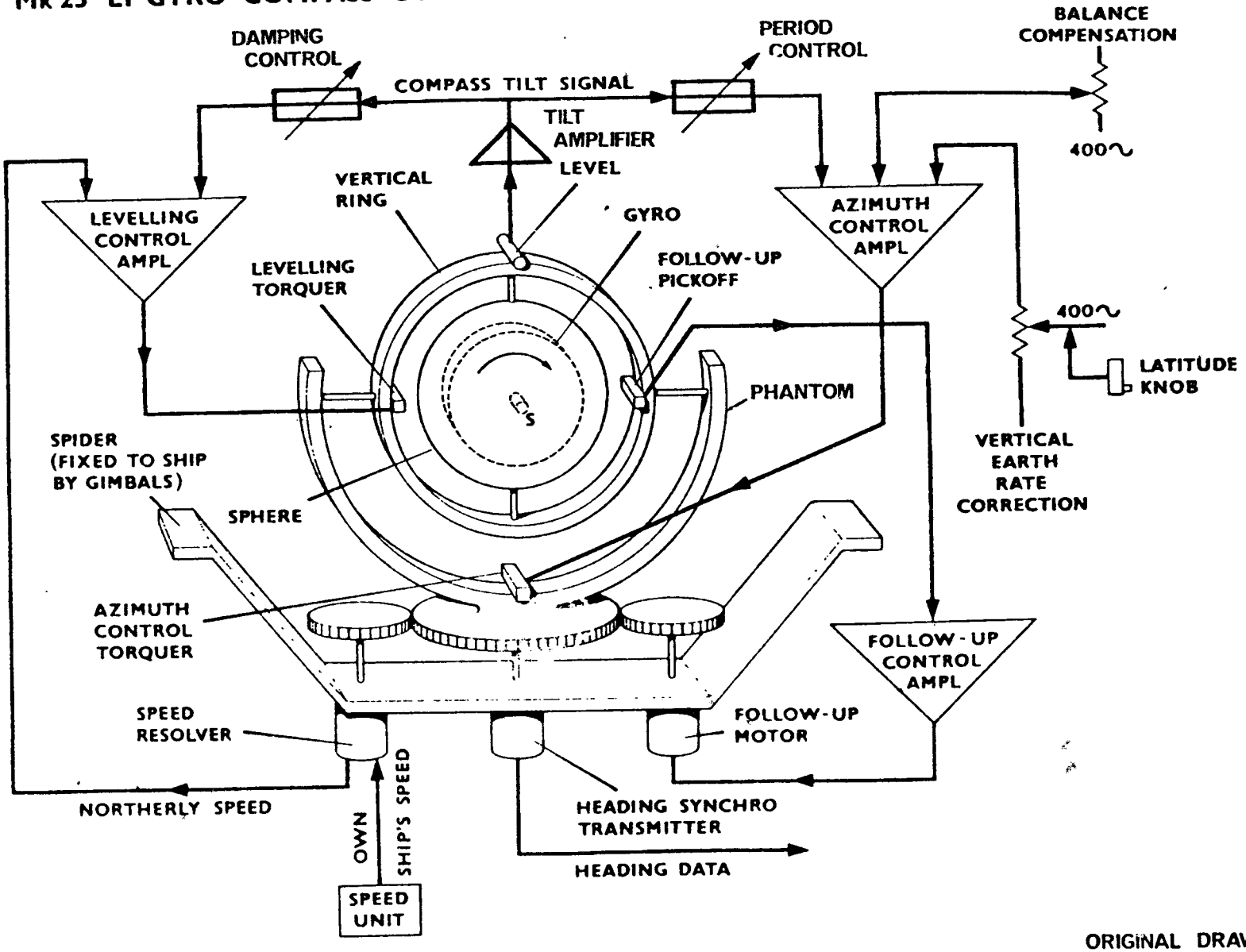
As the torque produced by the torquers is proportional to the product of their respective field voltages assuming the phase relationship is maintained at 90°, any power line voltage variations affecting either field would produce a varying torque for a given input. Such a variation, if uncorrected, would produce variable errors in the compass heading.

The method of compensation for line voltage variations is to leave the fixed fields of the torquers uncompensated and to compensate the excitation voltage supply to the control signal sources. The compensation is such that the excitation voltages to the compensating controls are changed by the % of any power line change but in the opposite sense, eg if power line drops, excitation voltage rises, thus maintaining constant torque from the torquers for a given input.

ii. Balance Compensation Fig 10

The requirement is to produce a voltage which, when applied to the azimuth torquers, will cause the axis to precess at a rate directly proportional and in opposition to the precession rate of the gyro caused by any constant unwanted torque operating about the horizontal axis of the sensitive element. Directional sense is obtained by positioning a switch in the compass control panel to either N-HIGH or S-HIGH position since any drift in azimuth from the meridian will eventually manifest itself in tilt of the spin axis due to E.L.R. This effect will be observed on the tilt meter.

# Mk 23 - LI GYRO COMPASS CONTROL SYSTEM (SCHEMATIC)




ORIGINAL DRAWING AMENDED
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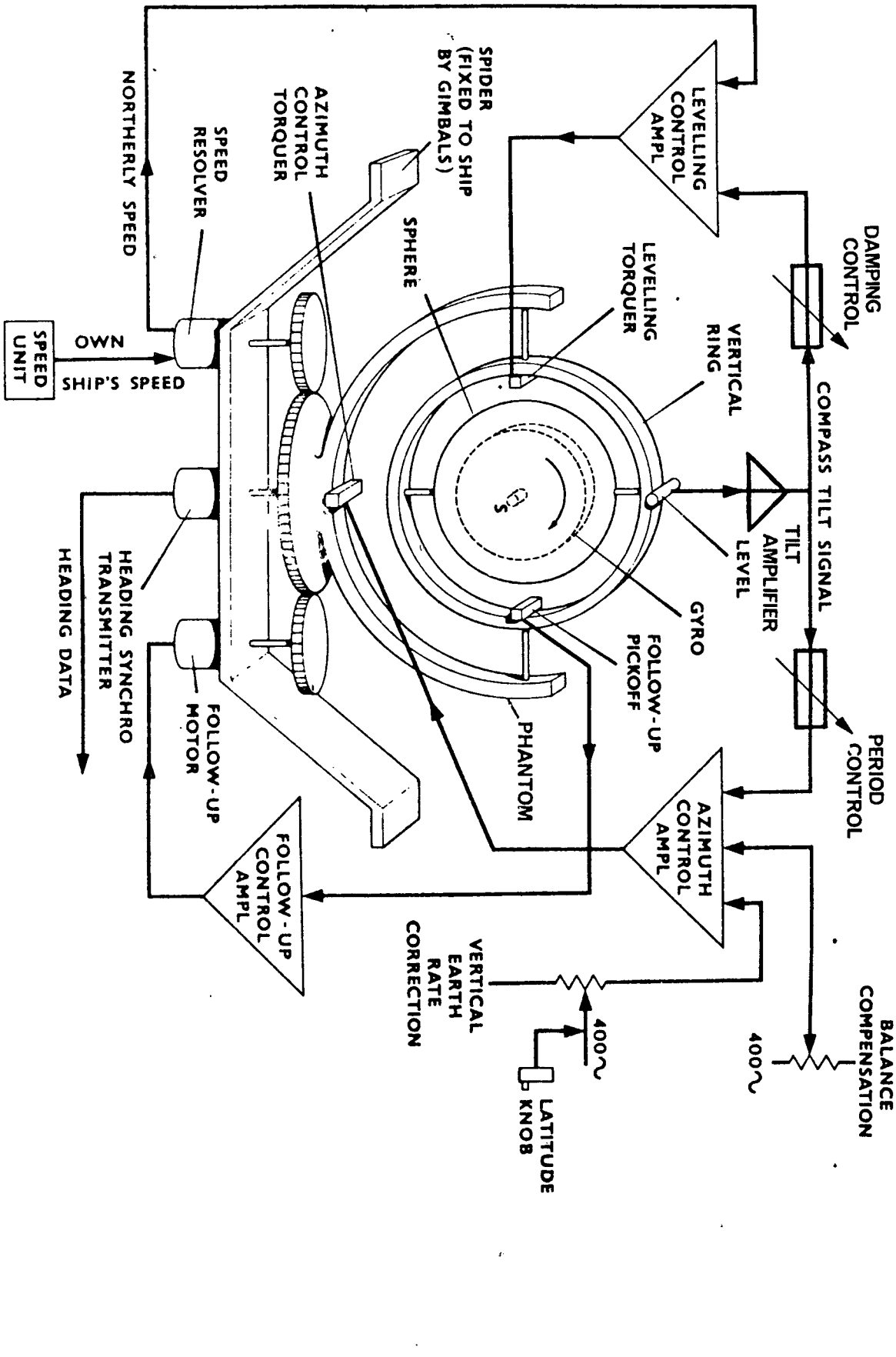
1353

# Mk 23-LI GYRO COMPASS CONTROL SYSTEM (SCHEMATIC)




ORIGINAL DRAWING AMENDED

DP 69/1920

8.

ii. Slewing Fig 10

Also included in the follow up system is Slewing Control. Operation of the Manual Azimuth Switch marked c.w. and c.c.w. with an OFF position, will control the follow up servomotor to slew the sensitive element to the ship's head as close as possible enabling the compass to settle in a minimum time when starting.

The input signal to the azimuth follow up amplifier and follow up motor for SLEWING is only provided when the operations switch is in the CAGE position.

It will be appreciated that although it is possible to slew with the gyro up to speed, the practice is not recommended, since the effect of the torques on the gyro will cause oscillations in tilt of the spider assembly about the roll and pitch axes. Slew rate is one azimuth in 15-30 seconds.

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As the torque produced by the torquers is proportional to the product of their respective field voltages assuming the phase relationship is maintained at $90^{o}$, any power line voltage variations affecting either field would produce a varying torque for a given input. Such a variation, if uncorrected, would produce variable errors in the compass heading.

The method of compensation for line voltage variations is to leave the fixed fields of the torquers uncompensated and to compensate the excitation voltage supply to the control signal sources. The compensation is such that the excitation voltages to the compensating controls are changed by the % of any power line change but in the opposite sense, eg if power line drops, excitation voltage rises, thus maintaining constant torque from the torquers for a given input.

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iii. Vertical Earth's Rate Effect Fig 10

The requirement is to develop a voltage proportional to 15 sin lat.°/hr. to compensate for the effect of V.E.R. if the compass is to settle level and on the meridian. A fixed voltage is derived from the voltage compensator proportional to 15°/hr. and applied to a SET LATITUDE potentiometer manually adjusted for the operating latitude. Movement of this potentiometer in accordance with a scale permits setting for the local latitude up to 90° N or S, thus producing an output voltage which will vary at 15 sin lat. °/hr., the phase of the output depending upon whether latitude is N or S.

Note: The potentiometer is linear whereas the dial scale is a sine function.

iv. North/South Speed Effect Fig 10

To compensate for this effect, a voltage proportional to ship's speed is derived from a linear potentiometer (supplied from the voltage compensator) operated either by hand or from an input from ship's log. This voltage is resolved into the N/S speed component (V cosine course) by a speed resolver. This signal voltage is required to produce a precession in tilt in opposition to tilt of the spin axis, at a rate equal to the Ship's N/S Angular rate. The voltage is summed in the levelling mixer unit, with the damping signal voltage, amplified in the Levelling Torquer amplifier and applied to the Levelling Torquer.

EXPLANATION OF VOLTAGE COMPENSATOR MODULE

(In conjunction with Fig. 7)

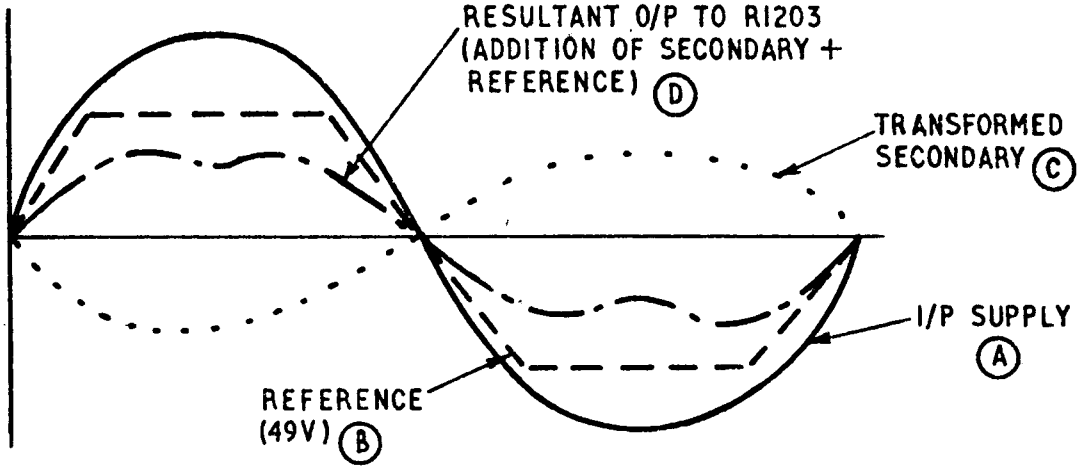



FIG.5 EXPLANATION OF VOLTAGE COMPENSATOR MODULE (IN CONJUNCTION WITH FIG.7)

f. Torquing Devices Fig 6

There are two azimuth torquers located diametrically opposite on the adaptor ring and in close proximity to the vertical ring, electrically connected together to exert a couple about the horizontal axis. Only one levelling torquer is fitted but each torquer is of the same construction with a common principle of operation.

They consist of an 'E' shaped laminated iron structure on the legs of which are wound 3 separate coils arranged in the form of a 2 phase motor field. The two coils on the outer legs are connected in series and form the control field which is excited from the output of the Azimuth or Levelling control amplifier. The coil on the inner leg is the fixed field and is connected to a fixed voltage source through a capacitor network. The output voltages to the control and fixed fields are 90° electrically out of phase.

The vertical ring (in the case of the azimuth torquers) could be considered as the rotor of a 2 phase induction motor. When the control windings are energised, the field set up cuts the vertical ring and induces currents in it which set up magnetic poles in the vertical ring. These try and align themselves with the moving field set up by the torquer and as a result the moving field tends to drag the vertical ring along with it. The magnitude of the resultant torque is proportional to the signal fed to the control winding and the direction of the torque is according to the phasing of the control field voltage.

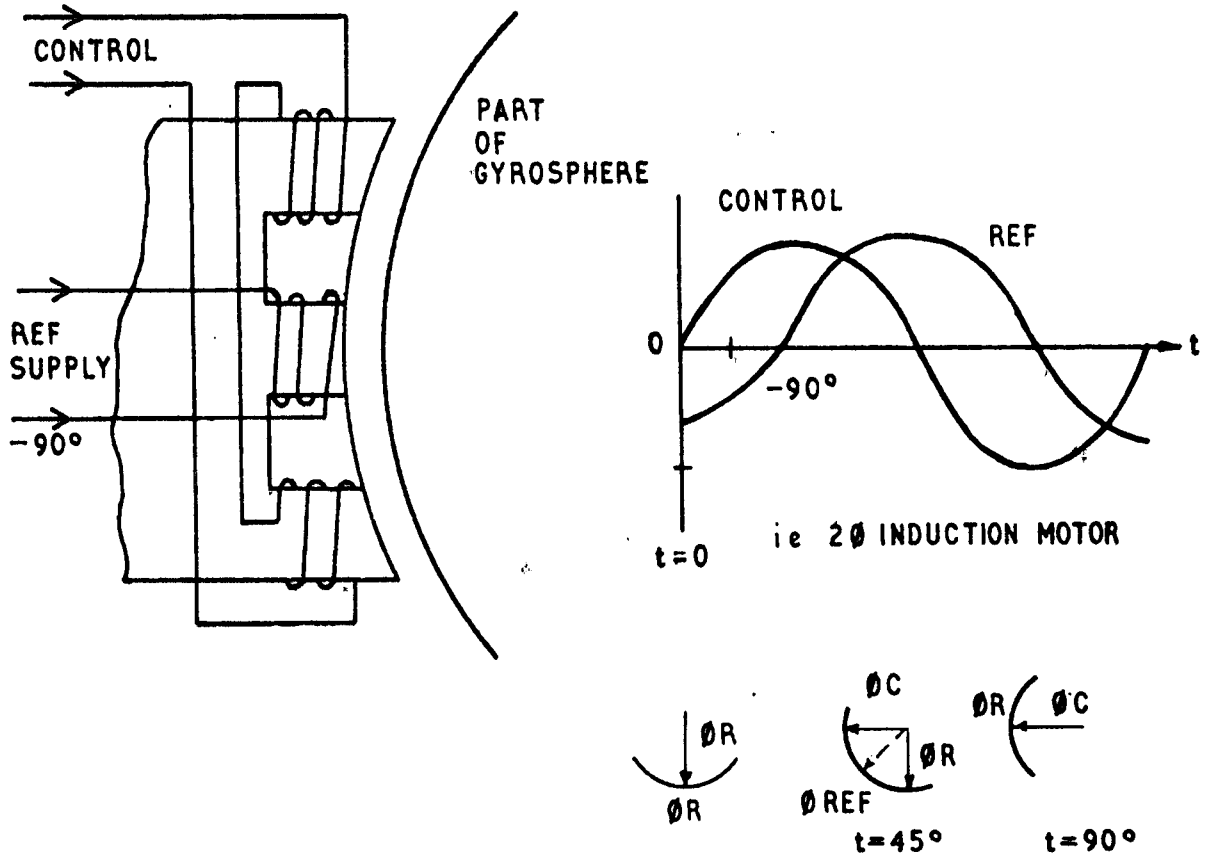



FIG. 6

g. D.C. Power Supply Module

Input is 115 V 400 Hz 3 phase ship's supply ± 7 V - frequency ± 15 Hz. The module develops d.c. voltages as follows:

28 V d.c. power supply for transistorised amplifiers.

160 V d.c. power supply for follow up alarm control and cager circuits.

The module also contains part of the caging circuitry and also part of the follow-up, 28 V and 160 V failure alarm circuitry.

h. Speed Unit - Two types fitted, ie 25 knt and 40 knt - Fig 8

The unit basically consists of a synchro motor driven from the output from the ship's log and positioned according to Ship's Speed. The synchro motor drives a linear potentiometer whose output supplies a voltage proportional to speed to the speed resolver on the master gyro unit. The synchro transmitter in the log equipment transmits to the synchro motor as follows:

1 knt change of speed = $9^{\circ}$ rotation of synchro motor in the 40 knt unit

and = $14.4^{\circ}$ rotation of synchro motor in the 25 knt unit.

The speed unit is not self-synchronous.

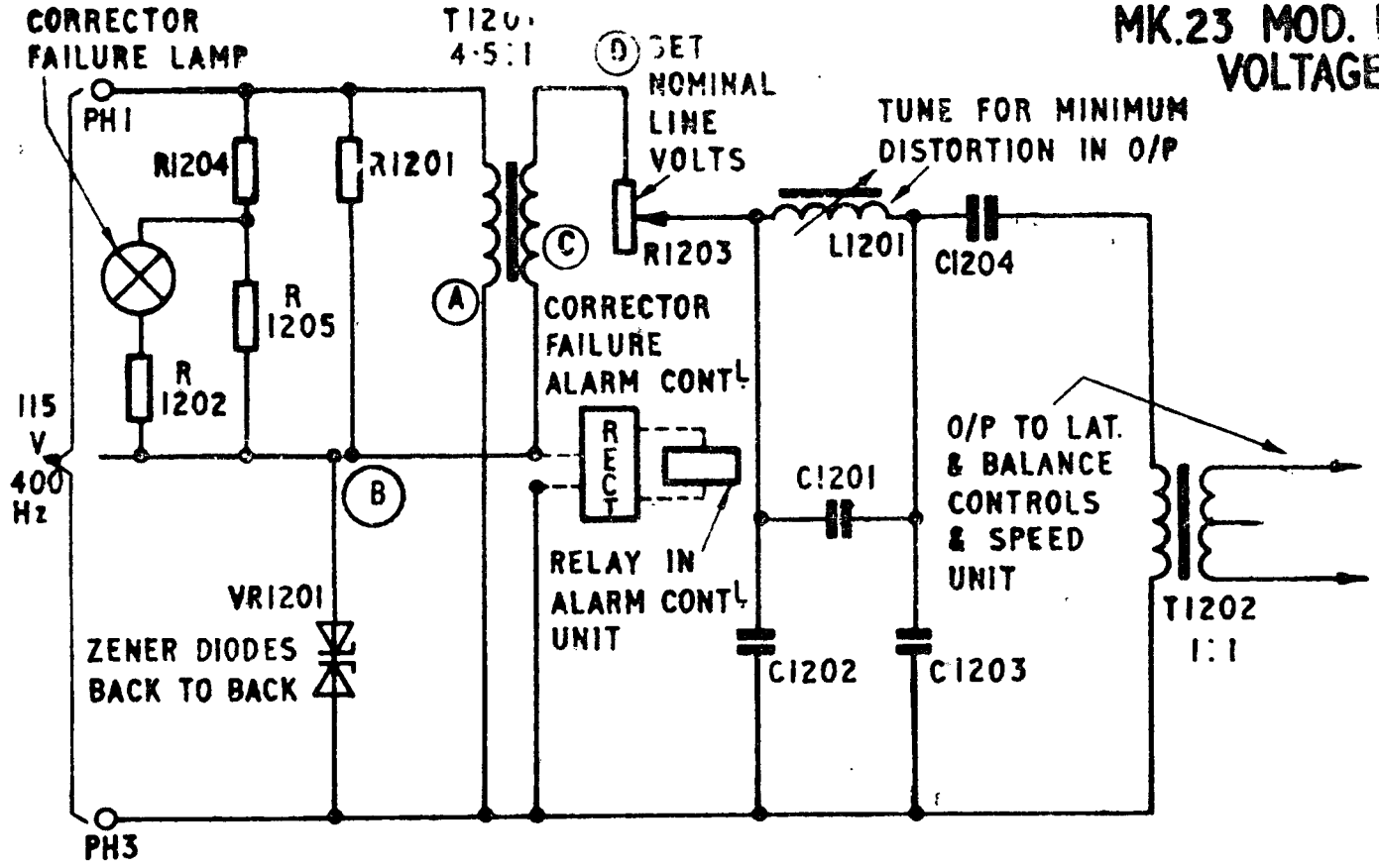
Manual operation of the linear potentiometer is also provided, speed being set on according to a scale.

These separate speed units have been replaced in ships fitted with a 2 compass installation by a single unit. It is known as the HORSTMAN speed transmission unit and consists basically of an 'M' type receiver motor driving the wiper arms of two linear potentiometers. The 'M' type receiver motor is electrically connected to an 'M' type transmitter in the EM Log Speed and distance transmitter.

Each linear potentiometer is fed with a reference voltage from the voltage compensator module in each compass control cabinet. The voltage output from the wiper arm of each linear potentiometer is proportional to Ship's Speed and is fed to the speed resolver of each master compass.

Manual operation to set a Ship's Speed is provided in the Unit.

# MK.23 MOD. L1 GYRO COMPASS VOLTAGE COMPENSATOR




12V. 400 Hz OUTPUT VARIES AS LINE VOLTAGE FLUCTUATIONS, AS LINE VOLTS INCREASE SO O/P DECREASES PROPORTIONALLY SINCE UNCOMPENSATED LINE VOLTS ARE SUPPLIED TO TORQUER FIXED FIELDS THEN AS FIXED FIELD VOLTS RISE, CONTROL FIELD VOLTS FALL BY THE SAME PERCENTAGE NET EFFECT:- NO CHANGE IN APPLIED TORQUE DUE TO LINE VOLTAGE VARIATIONS.

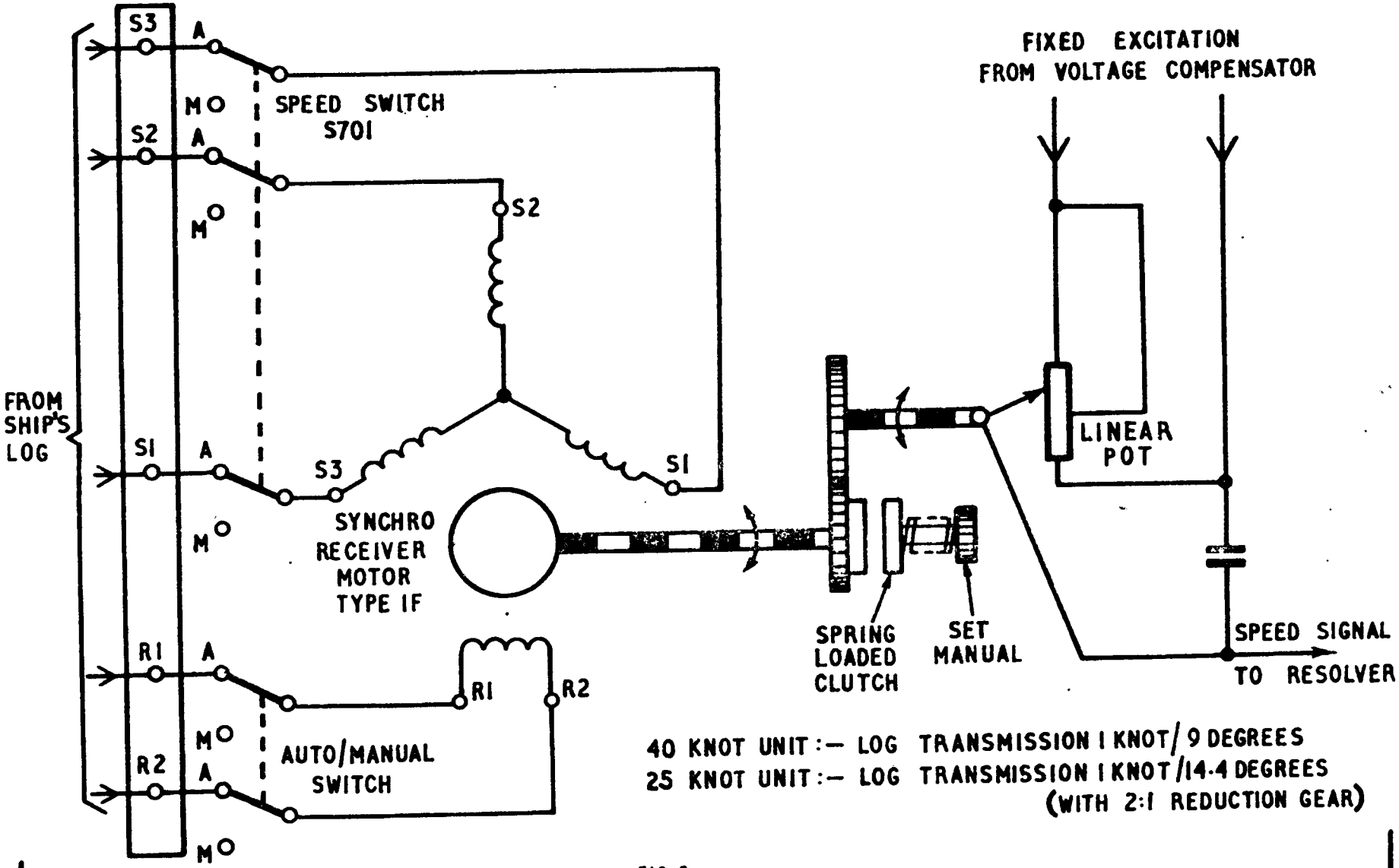
VR1201 :- CONSTANT VOLTAGE DEVICE (ZENER DIODE)
ANY VARIATION IN LINE VOLTS WILL NOT RESULT IN CURRENT VARIATION THROUGH R1201
VR1201. HENCE A.C. POTENTIAL AT (B) IS CONSTANT (49 VOLTS)

ALARM CONTROL :- WITH FAILURE OF VR1201 OR 115V. LINE VOLTAGE RELAY DE-ENERGISES.

| | |
|---|---|
| TR.1172 | R2 |
| DP.66/552f | |

# 25 KNOT SPEED UNIT — SCHEMATIC.

| TR 1175 | RI |
|---|---|
| DP66/552 i | |




40 KNOT UNIT :— LOG TRANSMISSION 1 KNOT/ 9 DEGREES
25 KNOT UNIT :— LOG TRANSMISSION 1 KNOT/14·4 DEGREES
(WITH 2:1 REDUCTION GEAR)

FIG 8

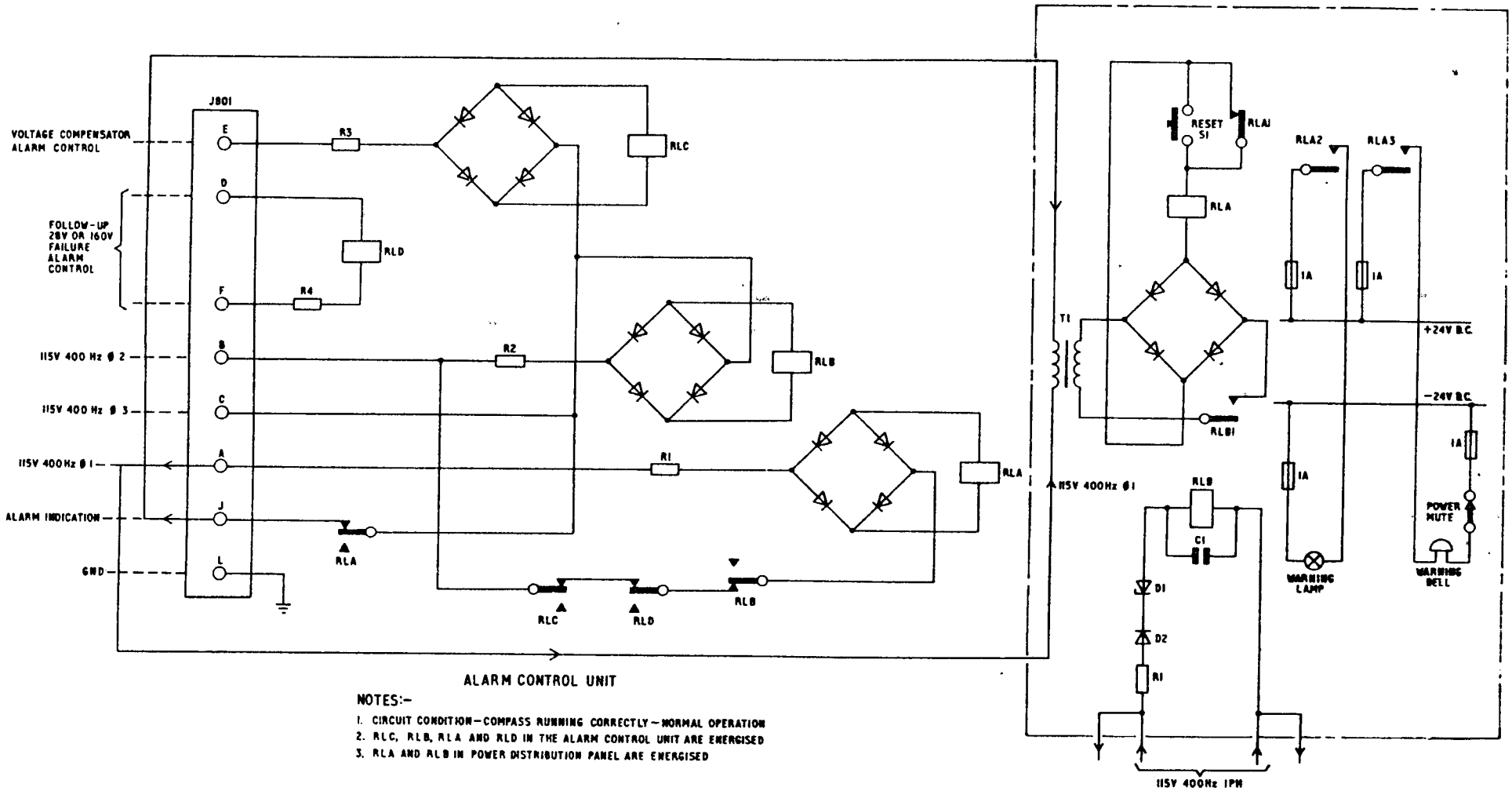
141

# ALARM SYSTEM MK 23 MOD 1 GYRO COMPASS SYSTEM

CAT. No E2064 R1
DP71/2675

## SINGLE INSTALLATION

## DUPLICATED FOR 2 COMPASS SYSTEM




ALARM CONTROL UNIT

NOTES:-

1. CIRCUIT CONDITION—COMPASS RUNNING CORRECTLY—NORMAL OPERATION
2. RLC, RLB, RLA AND RLD IN THE ALARM CONTROL UNIT ARE ENERGISED
3. RLA AND RLB IN POWER DISTRIBUTION PANEL ARE ENERGISED

PART OF POWER DISTRIBUTION PANEL

ALARM CONDITIONS TO BE INDICATED

1. VOLTAGE COMPENSATOR FAILURE
2. FOLLOW UP, 28V, OR 160V FAILURE
3. PHASE LINE FAILURE
4. 1 ø FAILURE

3. THE ALARM SYSTEM Fig 9

Its purpose is to provide Remote and Local alarm indication of certain failures which may occur in the Compass System.

An Alarm Control Unit for each Compass is fitted in the compass room and in conjunction with the alarm section of the Power Distribution Panel, will give warning by bell and lamp should the following failures occur:

a. Failure of Voltage Compensator output.
b. Failure of Follow-Up System.
c. Failure of internal 28 V or 160 V power supplies.
d. Any phase line failure of the 115 V 3 phase power supply input.
e. Failure of the 115 V 1 phase supply input.

Local alarm indication (lamp only) is provided on the control panel for Follow-Up and Voltage Compensator failures only.

Operation

a. Voltage Compensator Alarm (RLY C)

This relay is operated by the voltage (49 V) developed across the voltage regulator in the compensator circuit. If the voltage regulator fails for any reason then the relay will de-energise.

b. FU Alarm (RLY D)

When the Follow-Up system is operating correctly, this relay is energised via the 160 V d.c. supply, alarm reset switch, and conditions in the power supply module. In the event of FU failure ie FU failure switch on vertical ring of compass is actuated, the relay will de-energise due to the short circuit imposed on it by the conditions set in the power supply module.

c. 28 V and 160 V Alarm (RLY D)

In the event of these supplies failing this relay will de-energise due to conditions set in the power supply module.

d. 115 V Three Phase Line Failure Alarm

Lines 1 and 3 will cause relay C to de-energise (power supply and voltage compensator supply lines).
Lines 2 and 3 will cause relay B to de-energise.
Lines 1 and 2 will cause relay A to de-energise. Normally this relay is energised via the contacts of relays RL B, RL D, and RL C.
Relay A is the ALARM ACTUATOR RELAY (Inside P.D.P.)
In the event of any of the above failures occurring then the Alarm Actuator Relay will de-energise.
One set of contacts of Rly A, the Alarm Actuator relay, is used to energise the external alarm system transformer T1 in the Power Distribution Panel via phase lines 1 and 3. The secondary of T1 is connected to energise the Alarm Relay RLY A via RLY B contact and reset switch S1/hold-on contact A1.

e. 115 V Single Phase Failure Alarm

In the event of the single phase supply failure relay B will de-energise.

External Alarm System

In the event of any failure, Relay A in the P.D.P. will de-energise resulting in 24 V being connected to operate the alarm bells and light the Compass Warning Lamps.

16.

4. MODES OF OPERATION AND SWITCH ARRANGEMENTS Fig 10

a. Two modes of compass operation are provided as follows:

i. Normal

In this mode all controls are applied to the gyro compass control system and the compass period should be between 86 and 106 minutes with the damping between 61 and 75% at latitude 50°. The latitude switch is set at 45° for latitudes below 60° and at 65° for latitudes 60° and above. Above 75° latitude, the period of the compass lengthens considerably due to the decreasing rate of H.E.R. and the accuracy is thereby impaired.

ii. Directional Gyro

This mode is for use above latitude 75° and when selected by the appropriate switch position, the gyro operates as a free gyroscope corrected for V.E.R. and residual unbalance.

b. Power Switch

Has 4 positions, viz OFF, AMPL, GYRO, OFF.

i. Position AMPL - In this position power is supplied to all amplifiers and heading synchros. In addition, checks and tests on the amplifiers may be carried out without the gyro rotor running.

ii. Position GYRO - In this position power is supplied to the gyro stator windings, amplifiers and heading synchros.

c. Operations Switch - Has seven positions and selects the various modes of gyro control as follows:

i. CAGE - The gyro is caged so that the spin axis is in the locked condition. The 160 V d.c. supply to the caging coils is open-circuited and the meridian and levelling control signals are disconnected. Slewing control is operative.

ii. UNCAGE - Power is applied to the 'pulling' and 'holding' coils of the cager and the plunger is withdrawn. Power is removed from the Slewing control. The Meridian and Levelling signals are disconnected.

iii. LEVEL - The gyro is quickly brought to the LEVEL condition. The output from the electrolytic level is applied to the levelling torquer and increased torque for quick levelling is obtained by increasing the fixed field excitation to the torquers from the normal 6 V to 60 V. The meridian control signal is disconnected and the azimuth follow up system is energised.

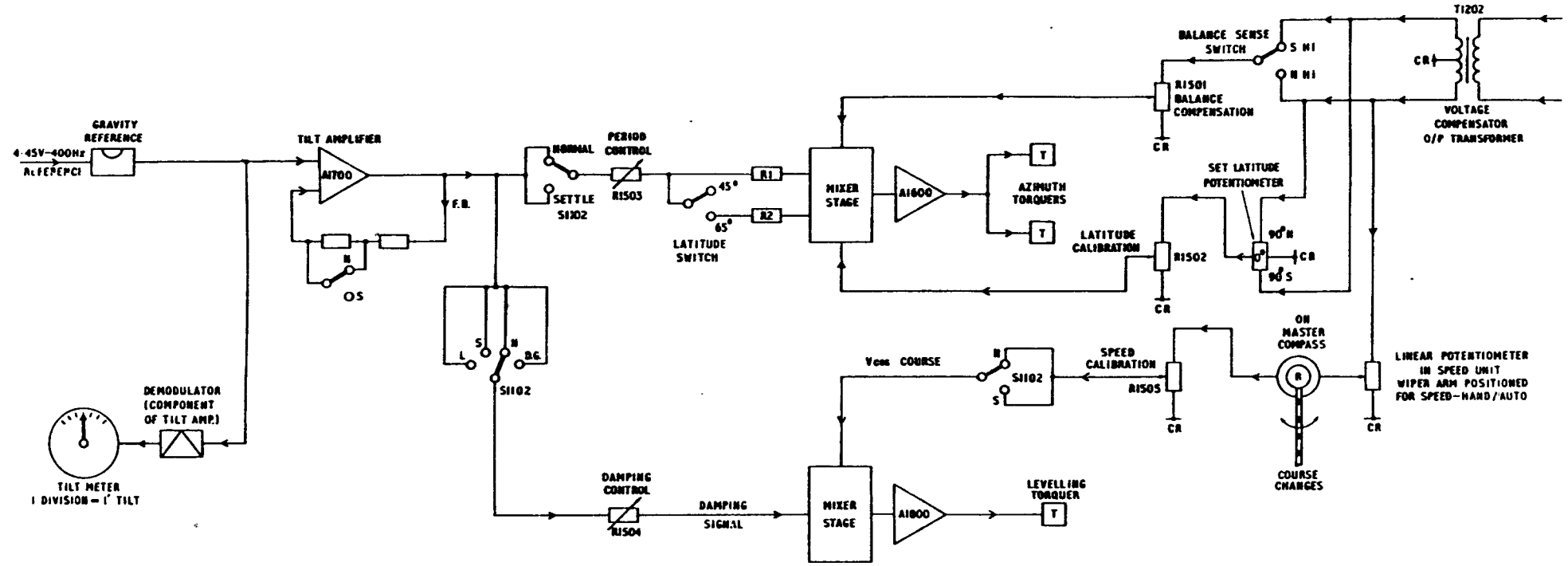
iv. SETTLE - All signals are connected, the compass period is 30 mins, damping is 90% approx. achieved by increasing the gain by 9 from normal of the meridian control and damping signals.

v. NORMAL - All signals are connected and the gain to both meridian control and damping signals is reduced to 1. Period is increased to within 86-106 mins and damping reduced to within 61-75%.

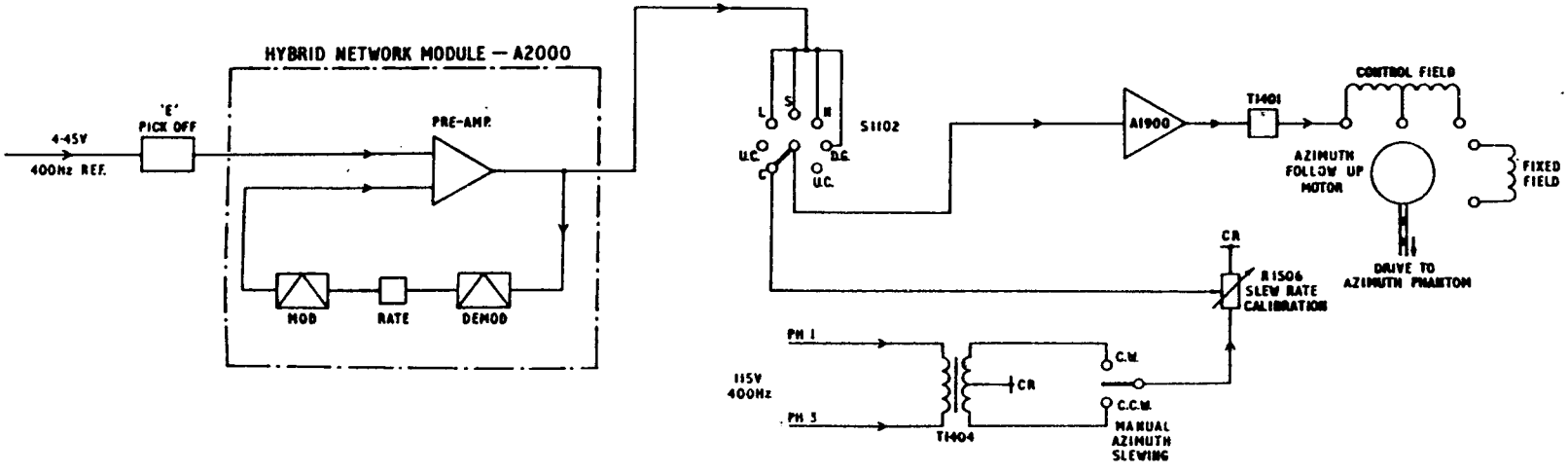
# MK 23 MOD LI GYRO COMPASS

## BLOCK SCHEMATIC CONTROL SYSTEM

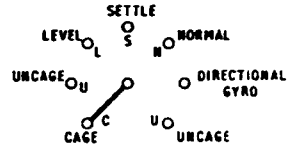
CAT No 'E2071' R1
D P No 71/2740




## AZIMUTH FOLLOW SYSTEM—BLOCK SCHEMATIC

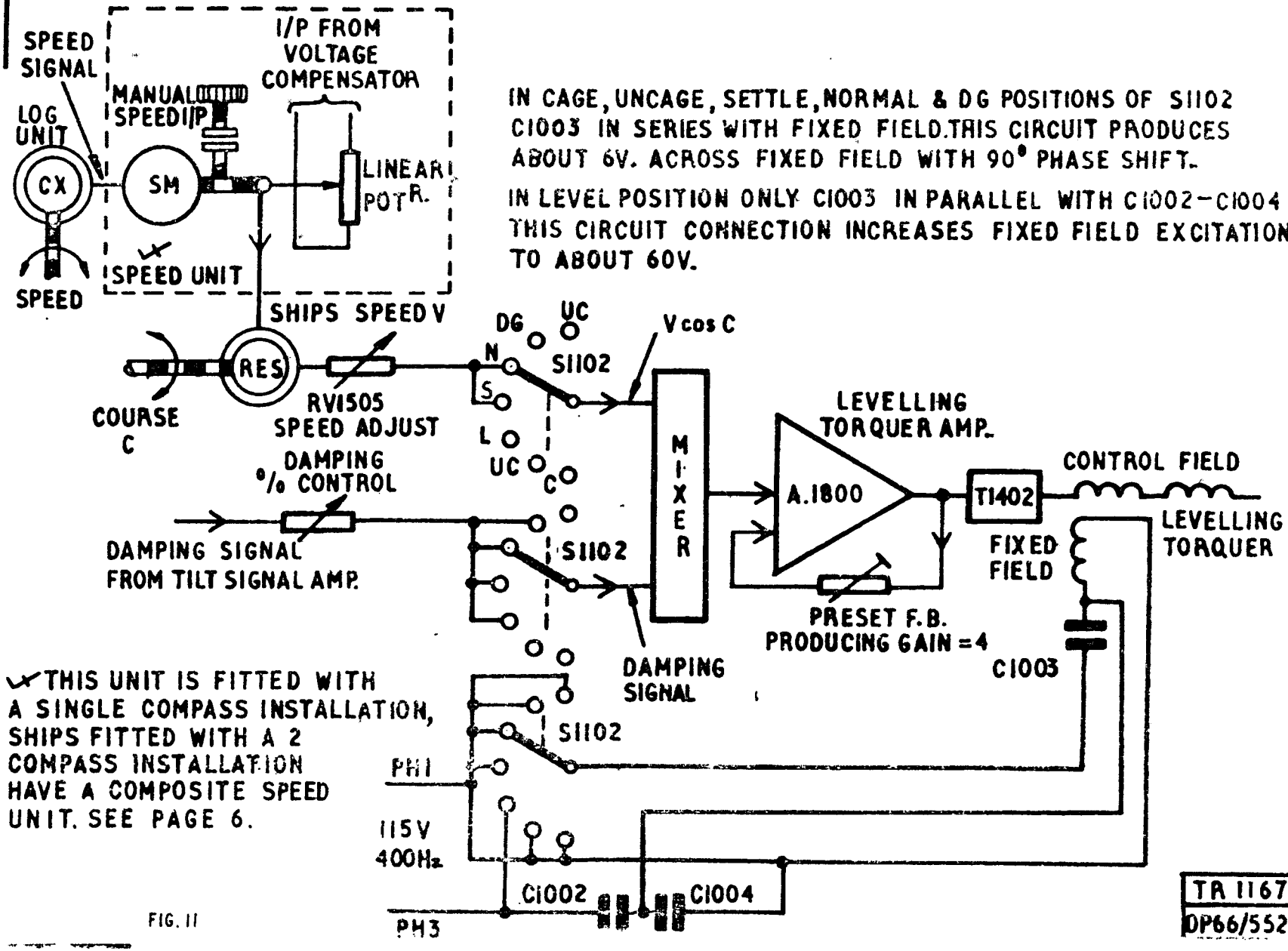



### OPERATIONS SWITCH (S1102)




145

# MK.23 MOD. GYRO COMPASS – LEVELLING CONTROL SYSTEM




IN CAGE, UNCAGE, SETTLE, NORMAL & DG POSITIONS OF S1102 C1003 IN SERIES WITH FIXED FIELD. THIS CIRCUIT PRODUCES ABOUT 6V. ACROSS FIXED FIELD WITH 90° PHASE SHIFT.

IN LEVEL POSITION ONLY C1003 IN PARALLEL WITH C1002–C1004 THIS CIRCUIT CONNECTION INCREASES FIXED FIELD EXCITATION TO ABOUT 60V.

✓ THIS UNIT IS FITTED WITH A SINGLE COMPASS INSTALLATION, SHIPS FITTED WITH A 2 COMPASS INSTALLATION HAVE A COMPOSITE SPEED UNIT. SEE PAGE 6.

FIG. 11

TR 1167 RI
DP66/552

vi. DIRECTIONAL GYRO - The meridian control and N/S speed signals are disconnected but the damping signal remains connected with the gain at 1, to maintain spin axis level. V.E.R. and balance compensation signals remain connected. Any discrepancy in V.E.R. compensation which in higher latitudes is approaching its maximum value would cause the axis to drift from the meridian with little or no indication from the tilt meter as H.E.R. effect is rapidly approaching zero. In addition to this, the effect of ship's E/W speed on V.E.R. becomes greater for which no compensation is allowed. Hence heading errors could become comparatively large.

vii. UNCAGE - This additional position is used conveniently when it is intended to directly assume Directional Gyro mode from the caged position.

5. CAGING MECHANISM

It is required to maintain the spin axis level and in alignment with the vertical ring prior to starting and during part of the starting cycle. The caging unit is attached to the spider and does not rotate with the phantom. To keep the caging plunger in the proper position to cage the gyro at any time, a slot in one end of the plunger extension rides over a guide on the phantom. So as the phantom turns, the plunger rotates with it enabling caging to take place at any heading.

The device is electromagnetic and consists basically of a pulling and holding coil and a spring loaded plunger carrying two rollers which press upwards on to the caging cams on the underside of the vertical ring, forcing the latter into the desired position.

Power is applied to the Pulling and Holding coils when the MODE switch is placed to UNCAGE. The spring loaded caging plunger is pulled down and, after approximately 1 second, the pulling coil is de-energised there being sufficient magnetomotive force from the holding coil to hold the plunger in the uncaged position.

A hydraulic device incorporated in the caging plunger mechanism causes a delay of 2 seconds before CAGING takes place. This is to prevent "nuisance" caging in the event of transient power fluctuations. Power at 160 V d.c. for the Pulling and Holding coils is obtained from the d.c. Power Module.

# CAGER CIRCUITRY MK. 23 MOD LI GYRO COMPASS

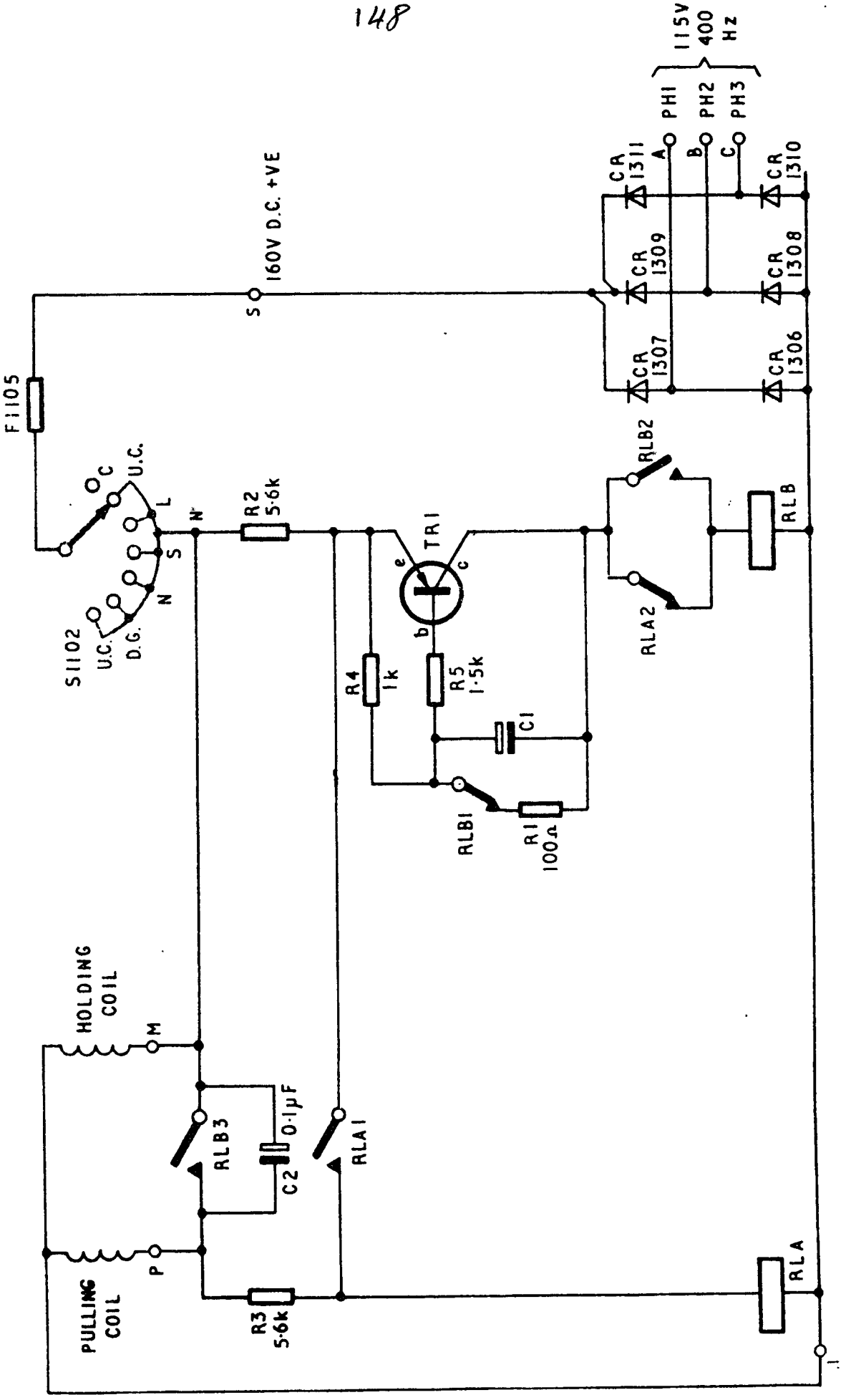



FIG 12

## STARTING PROCEDURE Fig 13

Preparations for starting the compass should begin at least two hours before it is required for service.

### Starting Conditions

i. Power switch to OFF. Check that power supplies are correct, ie 115 V 400 Hz 3 Ø and 1 Ø + 24 V.

ii. Operation Switch at CAGE.

iii. Latitude control at local latitude.

iv. Latitude switch (inside Control Cabinet) at 45 degree position for latitudes below 60 degrees or at 65 degree position for latitudes 60 degrees and above.

v. Set Speed Unit to MANUAL and set to zero.

### Starting Routine

i. Power Switch to AMPL.

ii. Slew compass by use of MANUAL AZIMUTH switch to set Master Unit compass card to ship's heading as closely as possible.

iii. Power Switch to GYRO and wait 10 seconds.

iv. Operation Switch to UNCAGE and wait 10 seconds. A loud click should be heard in the Master Unit indicating that the cager plunger has been withdrawn by the pull coil. Cager neon should glow momentarily.

v. Operation Switch to LEVEL and allow the gyro to come to a level condition as indicated by the tilt indicator. When the gyro is level the tilt indicator pointer will oscillate evenly about the zero position. (± 1 Division). RESET alarm relay on P.D.P. Check F.U. alarm and Corrector failure lamps are out. Switch on Alarm bell isolating switch.

### To Operate as a Normal Gyro Compass

vi. Operation Switch to SETTLE.

vii. After 30 to 40 minutes at SETTLE, set Operation Switch to NORMAL. Reset Alarm Relay if necessary.

viii. The equipment is now ready for use as a Gyro Compass. Set speed information as necessary by hand. (ie Leaving harbour)

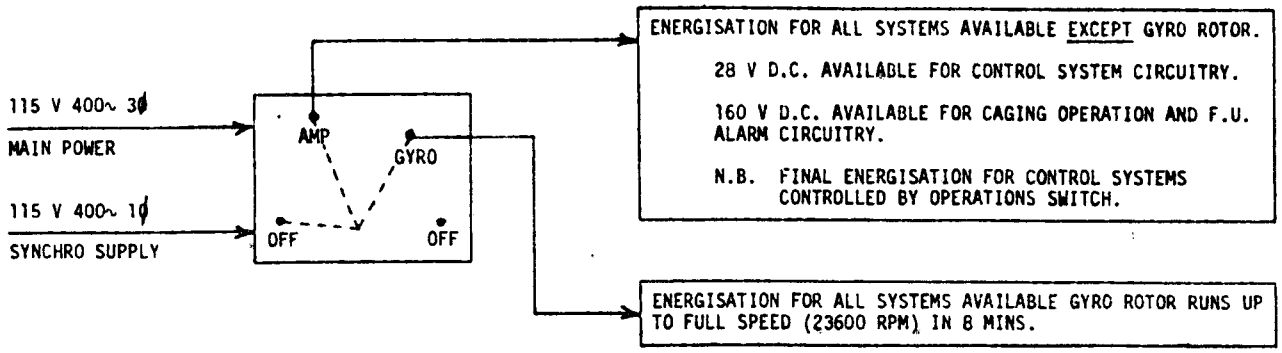
ix. When log is lowered (as ordered by Command). Set speed unit to ships speed and set to Auto. (Unit is non-synchronous)

### To Operate as a Directional Gyro

x. Operation Switch to D.G.

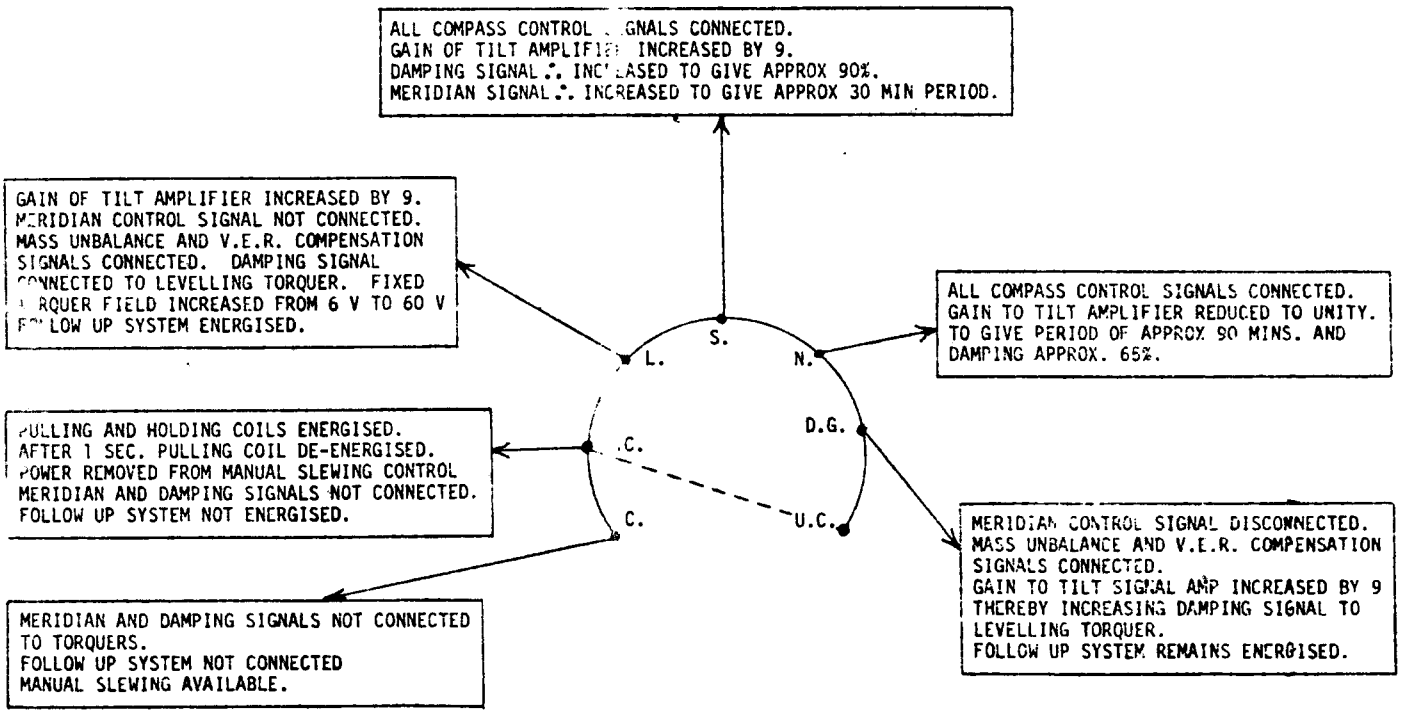
xi. The equipment is now ready for use as a Directional Gyro.

## POWER SUPPLY SWITCH MK 23 MOD L1


115 V 400~ 3ϕ
MAIN POWER
115 V 400~ 1ϕ
SYNCHRO SUPPLY
AMP
GYRO
OFF
OFF
ENERGISATION FOR ALL SYSTEMS AVAILABLE EXCEPT GYRO ROTOR.
28 V D.C. AVAILABLE FOR CONTROL SYSTEM CIRCUITRY.
160 V D.C. AVAILABLE FOR CAGING OPERATION AND F.U. ALARM CIRCUITRY.
N.B. FINAL ENERGISATION FOR CONTROL SYSTEMS CONTROLLED BY OPERATIONS SWITCH.
ENERGISATION FOR ALL SYSTEMS AVAILABLE GYRO ROTOR RUNS UP TO FULL SPEED (23600 RPM) IN 8 MINS.

N.B. AS MODULES ARE TRANSISTORISED NO WARM UP TIME IS REQ'D. POWER SWITCH CAN BE OPERATED DIRECT TO GYRO.

## OPERATIONS SWITCH MODE CONDITIONS MK 23 MOD L1


ALL COMPASS CONTROL SIGNALS CONNECTED.
GAIN OF TILT AMPLIFIER INCREASED BY 9.
DAMPING SIGNAL ∴ INCREASED TO GIVE APPROX 90%.
MERIDIAN SIGNAL ∴ INCREASED TO GIVE APPROX 30 MIN PERIOD.
GAIN OF TILT AMPLIFIER INCREASED BY 9.
MERIDIAN CONTROL SIGNAL NOT CONNECTED.
MASS UNBALANCE AND V.E.R. COMPENSATION SIGNALS CONNECTED. DAMPING SIGNAL CONNECTED TO LEVELLING TORQUER. FIXED TORQUER FIELD INCREASED FROM 6 V TO 60 V FOLLOW UP SYSTEM ENERGISED.
ALL COMPASS CONTROL SIGNALS CONNECTED.
GAIN TO TILT AMPLIFIER REDUCED TO UNITY.
TO GIVE PERIOD OF APPROX 90 MINS. AND DAMPING APPROX. 65%.
L.
S.
N.
D.G.
C.
C.
U.C.
PULLING AND HOLDING COILS ENERGISED.
AFTER 1 SEC. PULLING COIL DE-ENERGISED.
POWER REMOVED FROM MANUAL SLEWING CONTROL
MERIDIAN AND DAMPING SIGNALS NOT CONNECTED.
FOLLOW UP SYSTEM NOT ENERGISED.
MERIDIAN CONTROL SIGNAL DISCONNECTED.
MASS UNBALANCE AND V.E.R. COMPENSATION SIGNALS CONNECTED.
GAIN TO TILT SIGNAL AMP INCREASED BY 9 THEREBY INCREASING DAMPING SIGNAL TO LEVELLING TORQUER.
FOLLOW UP SYSTEM REMAINS ENERGISED.
MERIDIAN AND DAMPING SIGNALS NOT CONNECTED TO TORQUERS.
FOLLOW UP SYSTEM NOT CONNECTED
MANUAL SLEWING AVAILABLE.

Stopping Routine

Under normal conditions. Switch off alarm bell isolating switch.

i. Operation Switch to CAGE, wait 10 seconds then place Power Switch to OFF.

In heavy seas.

i. Power Switch to AMPL, wait 30 minutes then place Operation Switch to CAGE.

ii. Power Switch to OFF.

In the event of Follow-up failure, immediately place Operation Switch to CAGE and Power Switch to OFF.

# Stabilized Gyrocompass Set

## EQUIPMENT DESCRIPTION

1-11. GENERAL DESCRIPTION. The Gyrocompass Set, Stabilized, AN/WSN-2; provides precise output signals for ship heading, roll, and pitch. These outputs are in dual-speed synchro format. A backup power supply ensures that the system will function during loss of the ship's 400-Hz power. The backup power supply can sustain the vital heading output for up to 30 minutes. Built-in test equipment (BITE) circuits identify equipment faults and provide visual indications of the faulting assembly or subassembly. The equipment requires no operator after it is turned on and the desired mode of operation selected.

a. Relationship of Units. Gyrocompass Set, Stabilized, AN/WSN-2 consists of Cabinet, Electrical Equipment, CY-7623/WSN-2, (1A1) and five major assemblies contained therein. The major assemblies are Control-Indicator, ID-2112/WSN-2 (1A2); Control-Power Supply, C-10283/WSN-2 (1A3); Battery Set, BB-316/WSN-2 (1A4): Amplifier, Synchro Signal, AM-6947/WSN-2 (1A5); and Inertial Measuring Unit, MX-9904/WSN-2 (1A6). Cabinet, Electrical Equipment, CY-7623/WSN-2 contains a limited amount of electronics and a wiring harness that provides electrical interconnections between the major assemblies. The major assemblies are illustrated in figure 1-1 and described in paragraphs (1) through (6) following:

(1) Cabinet, Electrical Equipment, CY-7623/WSN-2 (Cabinet, 1A1). The cabinet is an enclosure for the five major assemblies of Gyrocompass Set, Stabilized, AN/WSN-2. It provides the mechanical and electrical interface for these major assemblies and provides forced air cooling for Inertial Measuring Unit, MX-9904/WSN-2 (IMU). The cabinet contains a wiring harness, alarm relays, an ac relay, EMI filters, an elapsed time meter, capacitor assemblies, a blower (for IMU cooling), and the IMU rack. A connector panel on the rear of the cabinet provides the electrical cable interconnections for all cabling to external equipment, including primary power.

(2) Control-Indicator, ID-2112/WSN-2 (Control-Indicator, 1A2). The control-indicator is a hinged assembly located in the top of Cabinet, Electrical Equipment, CY-7623/WSN-2 (cabinet). It is secured to the cabinet with quick-release fasteners. The control-indicator contains all of the operator controls and indicators for Gyrocompass Set, Stabilized, AN/WSN-2. The control-indicator also contains built-in-test equipment (BITE).

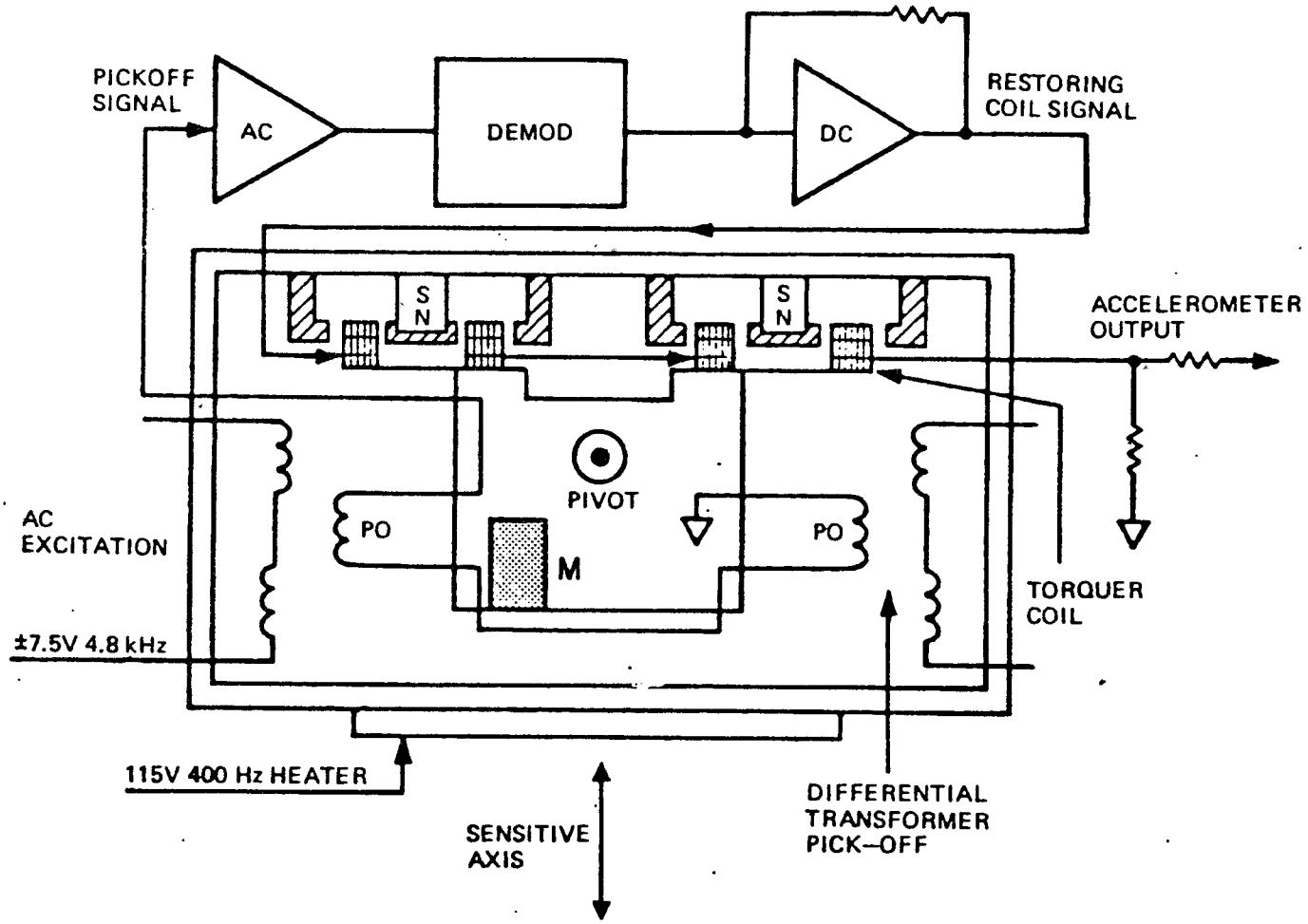
(3) Control-Power Supply, C-10283/WSN-2 (Control-Power Supply, 1A3). The control-power supply is installed on guide rails in Cabinet, Electrical Equipment, CY-7623/WSN-2 (cabinet) and may be extended from the cabinet by loosening quick release fasteners. The control-power supply contains the control, computing, processing, analog/digital conversion, input/output interface, and power supply electronics for Gyrocompass Set, Stabilized, AN/WSN-2. It also contains capacitor assemblies, cooling blowers, built-in test equipment (BITE) and the battery charger electronics for charging the battery contained in Battery Set, BB-316/WSN-2 (1A4).

(4) Battery Set, BB-316/WSN-2 (Battery Set, 1A4). The battery set is installed in Cabinet, Electrical Equipment CY-7623/WSN-2 (cabinet). It is secured in the cabinet by quick-release fasteners. The battery set contains a battery, isolation diodes, fuses, and sensing circuits. The battery consists of 60 sealed lead-acid storage cells, connected in parallel-series (five parallel branches, consisting of 12 cells per branch) to provide a nominal 24-volt output. The battery is under a continuous charge, provided by electronics contained in Control-Power Supply, C-10283/WSN-2. The fuses provide overload protection in the battery charger input lines and the battery output. The sensing circuits consist of a high voltage sensing circuit, a low voltage sensing circuit, and a temperature sensing circuit. The outputs of these sensing circuits go to built-in test equipment (BITE) circuits contained in Control-Power Supply, C-10283/WSN-2.

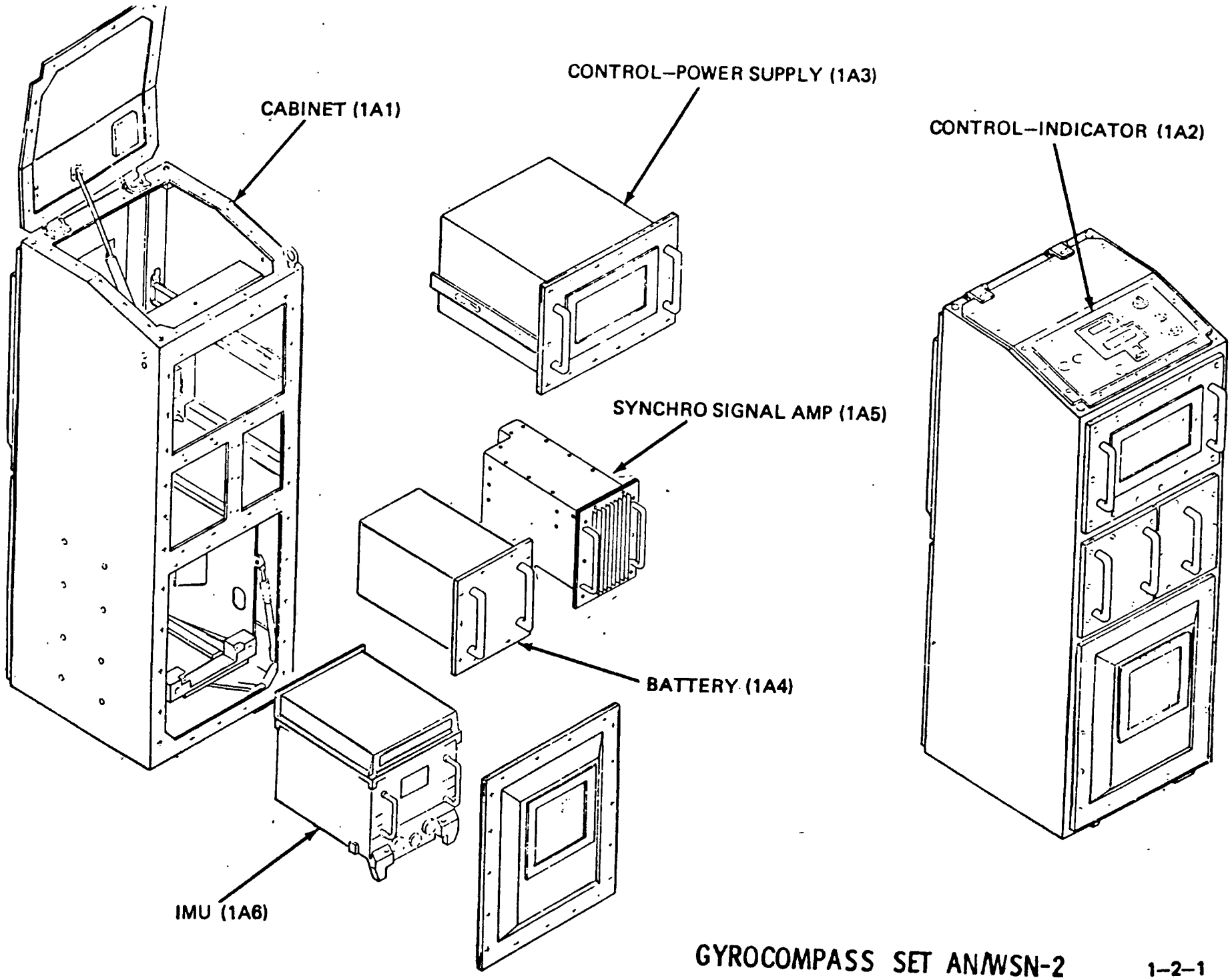
(5) Amplifier, Synchro Signal AM-6947/WSN-2 (Synchro Signal Amplifier, 1A5). The synchro signal amplifier is installed in Cabinet, Electrical Equipment, CY-7623/WSN-2 (cabinet). It is secured in the cabinet by quick-release fasteners. The synchro signal amplifier contains four

synchro buffer amplifiers, an inverter power supply, a cooling blower and built-in test equipment (BITE). The synchro buffer amplifiers provide the voltage and power levels for the Gyrocompass Set, Stabilized, AN/WSN-2 heading, pitch, and roll synchro output signals. The inverter power supply converts the battery output to the proper dc levels for the synchro signal amplifier. It provides ac power for the equipment cooling fans and a vital heading reference output for the Gyrocompass Set, Stabilized, AN/WSN-2. The inverter power supply also contains BITE summary logic for the synchro signal amplifier.

(6) Inertial Measuring Unit, MX-9904/WSN-2 (IMU, 1A6). The IMU is installed in a special, precision IMU rack located in the bottom of Cabinet, Electrical Equipment, CY-7623/WSN-2 (cabinet), behind an access cover. Access to the IMU is gained by removal of the access cover. The IMU contains the gimbal assembly, the electronics necessary to maintain the gimbal assembly, and associated electronics necessary to interface with the control, computing, and processing functions of Control-Power Supply, C-10283/WSN-2. The IMU also contains built-in test equipment (BITE) and cooling blowers.




ACCELEROMETER SIGNALS

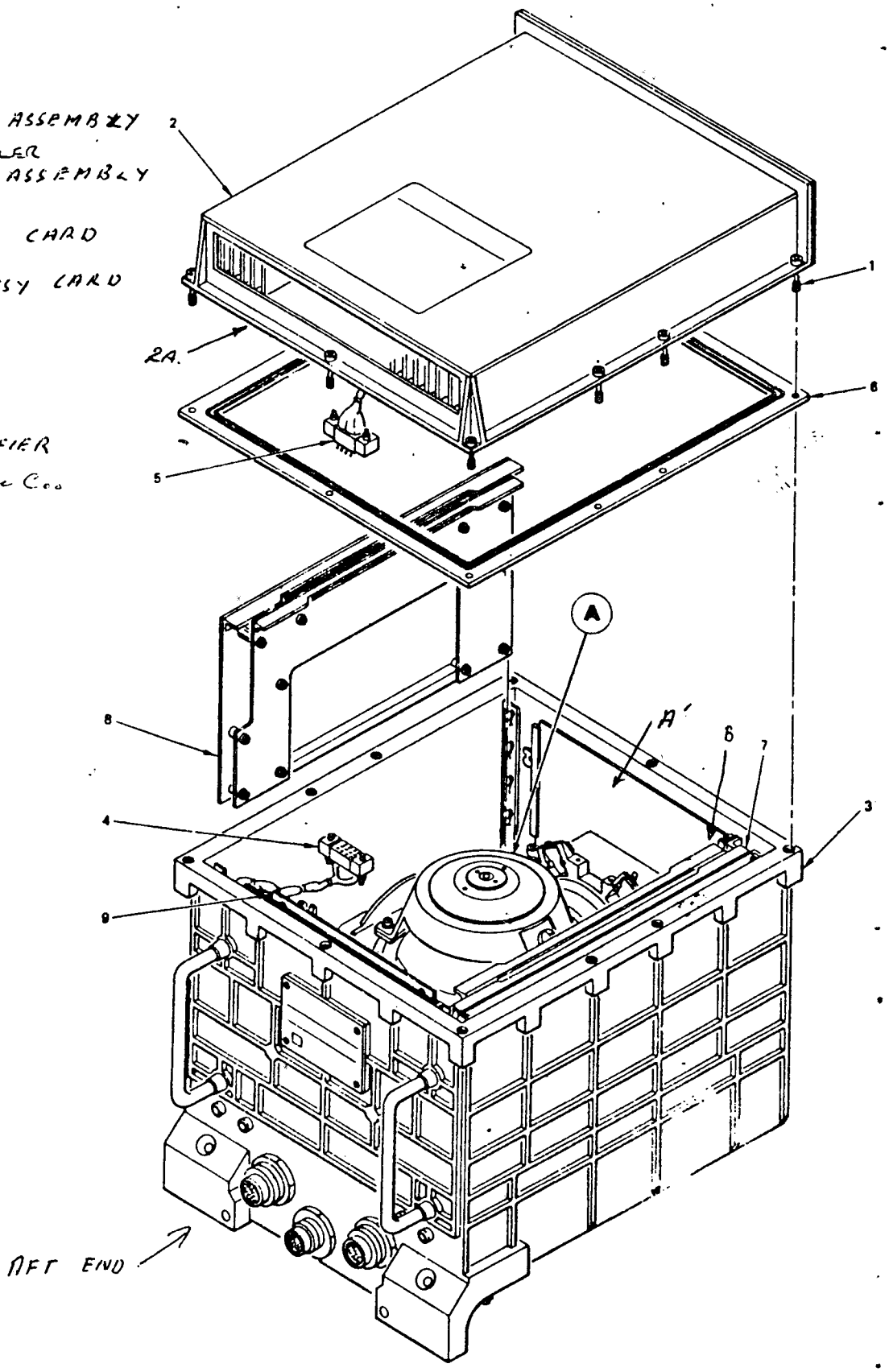



GYROCOMPASS SET AN/WSN-2

1-2-1

I-11

2, UPPER IMU SUB ASSEMBLY
2A 3 MODE TEMP CONTROLLER
3, LOWER IMU SUB ASSEMBLY
~~4~~ 7 QUANTISER CIRCUIT CARD
~~7~~ 8 SERVO AMPLIFIER ASSY CARD
9 GYRO SPIN CARD
~~A~~ SERIAL DATA CARD
6 RESOLVER PREAMPLIFIER
No give correct since Coo



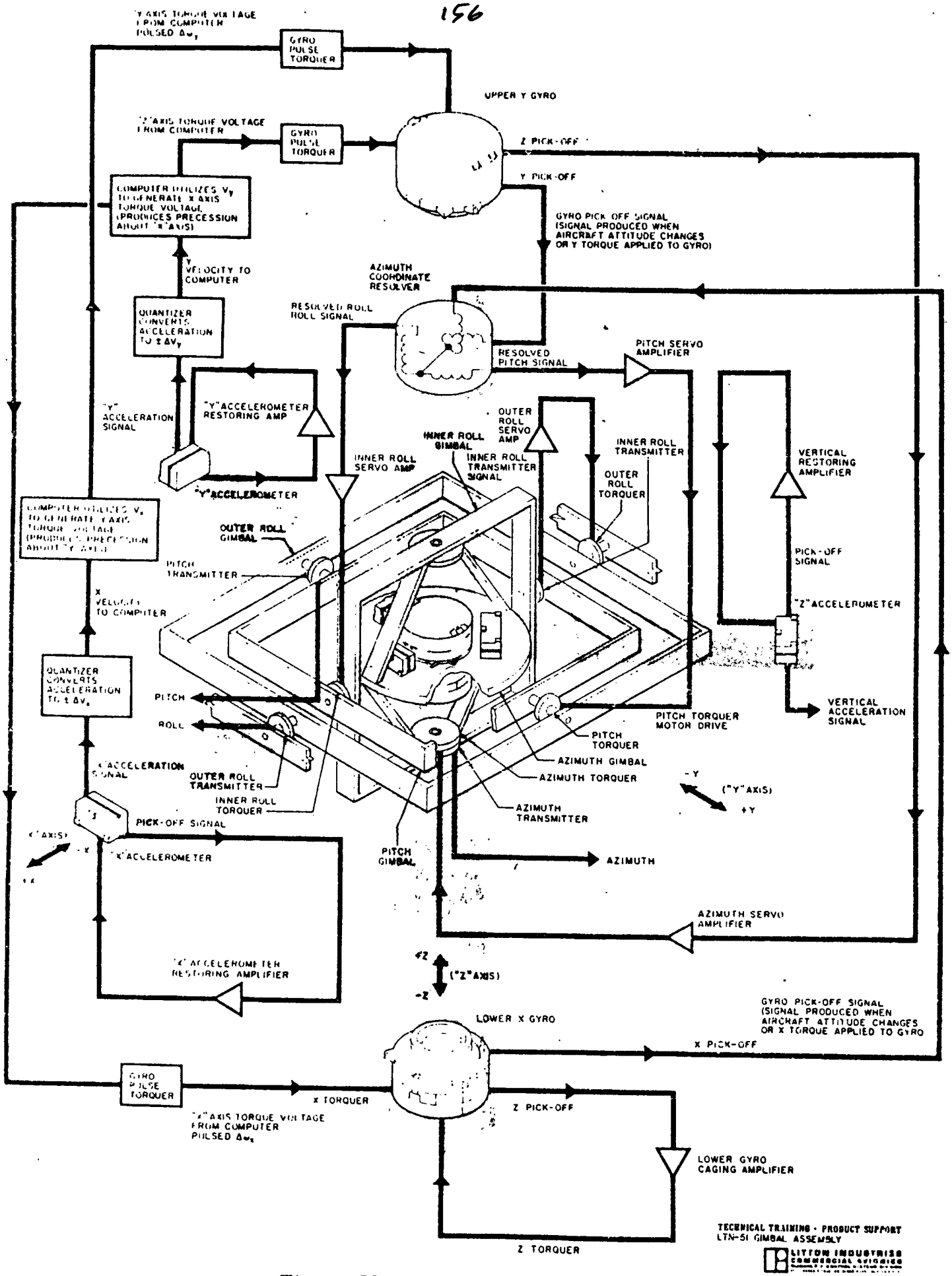
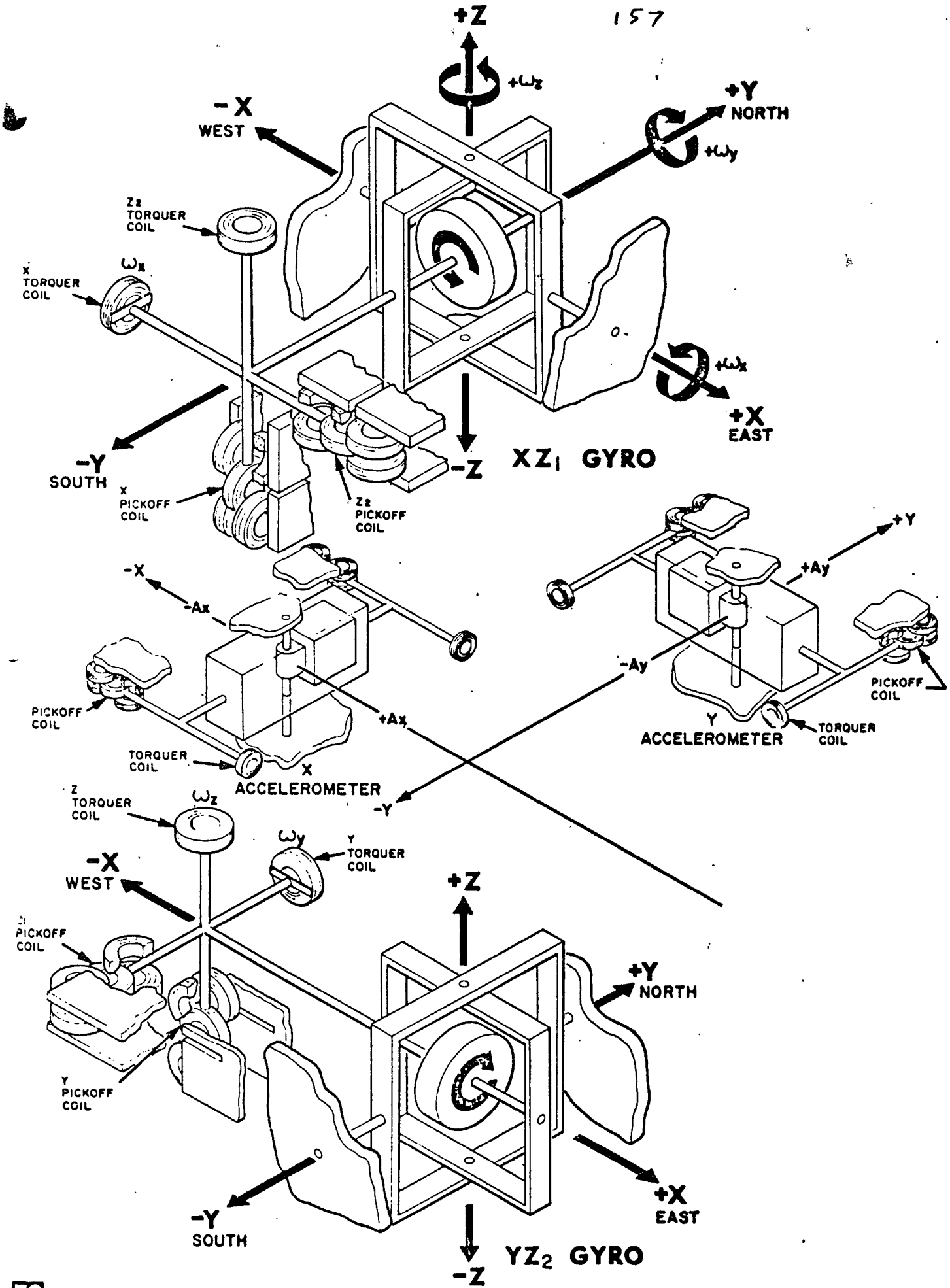
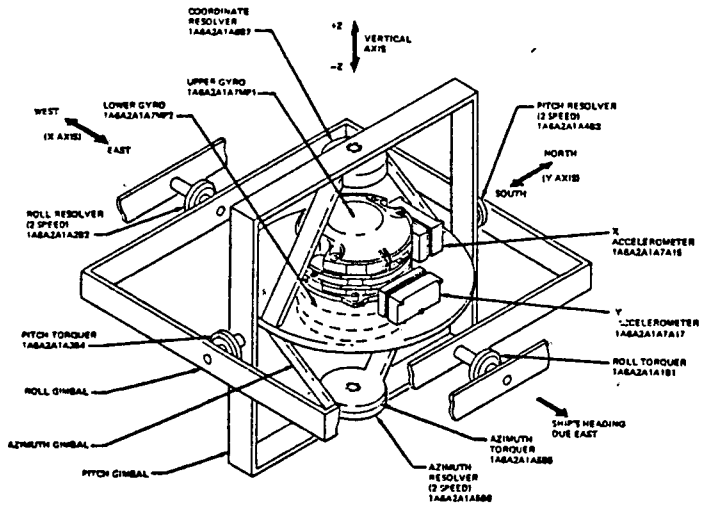


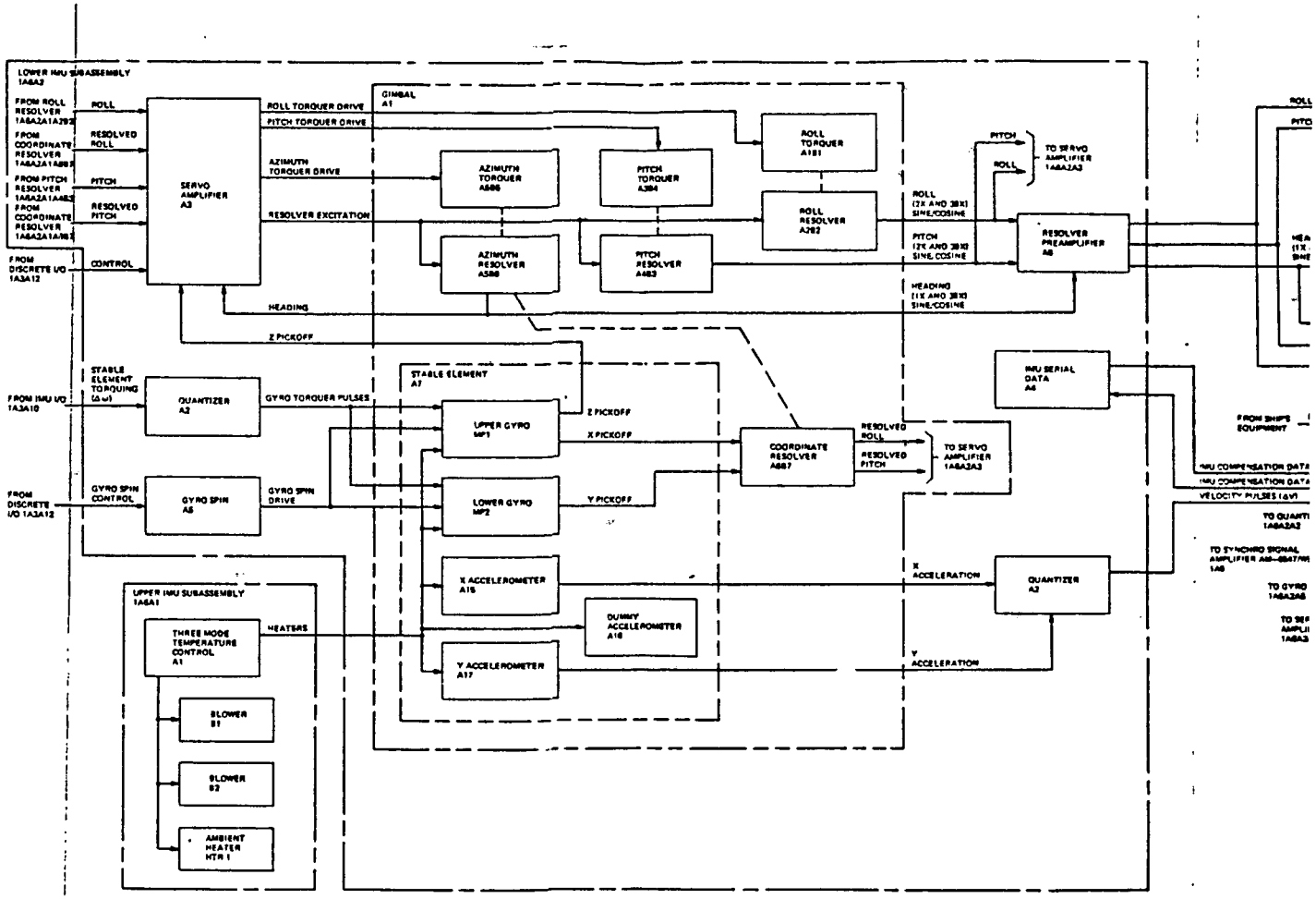

Figure 53. A Semi-Analytic Inertial System

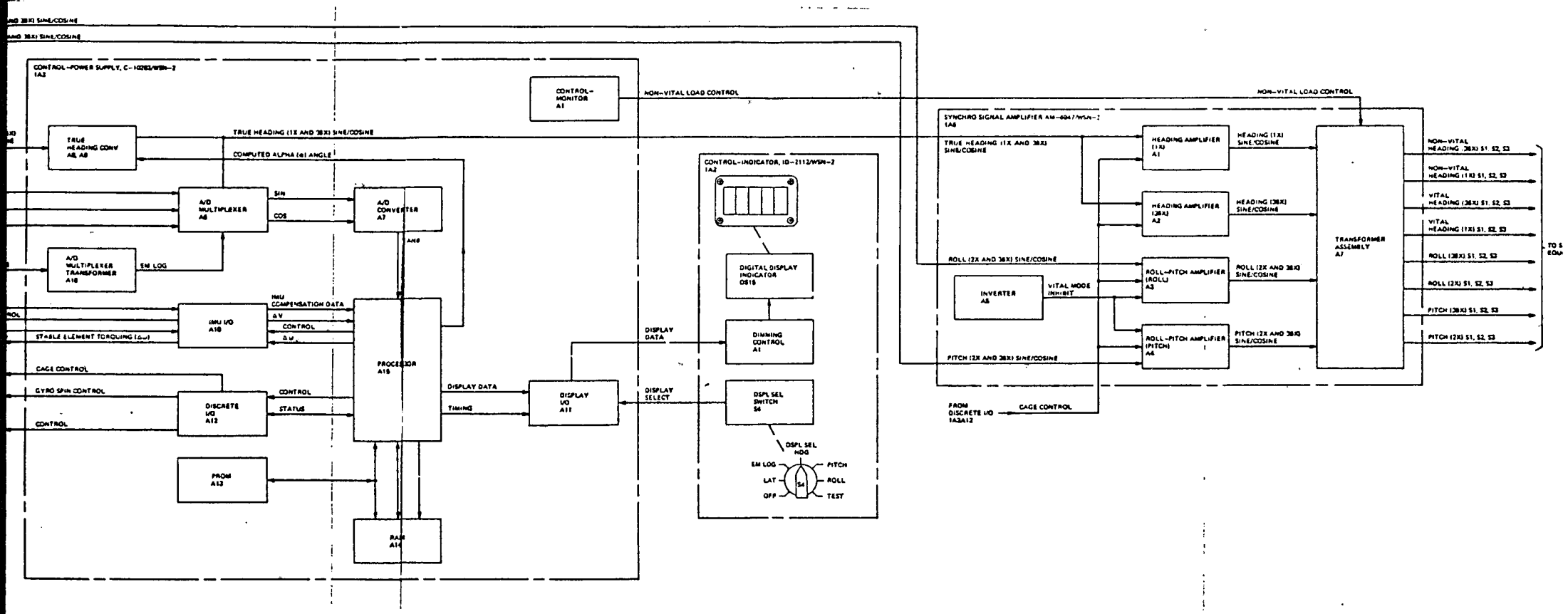

+Z
+ωz
-X
WEST
+Y
NORTH
+ωy
Zz TORQUER COIL
X TORQUER COIL
ωx
+ωx
+X
EAST
-Y
SOUTH
-Z
XZ1 GYRO
X PICKOFF COIL
Zz PICKOFF COIL
-X
-Ax
+Ax
PICKOFF COIL
TORQUER COIL
X
ACCELEROMETER
+Y
+Ay
-Ay
PICKOFF COIL
Y
TORQUER COIL
ACCELEROMETER
-Y
Z TORQUER COIL
ωz
ωy
Y TORQUER COIL
-X
WEST
+Z
PICKOFF COIL
+Y
NORTH
Y PICKOFF COIL
+X
EAST
-Y
SOUTH
-Z
YZ2 GYRO

GENERAL NOTES:

A. PARTIAL REFERENCE DESIGNATORS ARE SHOWN. FOR COMPLETE DESIGNATORS PREFIX WITH ASSEMBLY AND UNIT DESIGNATORS




CONTROL-POWER SUPPLY, C-10283/WSN-2
1A3
CONTROL-MONITOR
A1
NON-VITAL LOAD CONTROL
TRUE HEADING CONV
A8, A9
TRUE HEADING (1X AND 36X) SINE/COSINE
COMPUTED ALPHA (α) ANGLE
A/D MULTIPLEXER
A6
SIN
COS
A/D CONVERTER
A7
A/D MULTIPLEXER TRANSFORMER
A10
EM LOG
IMU I/O
A10
IMU COMPENSATION DATA
ΔV
CONTROL
Δω
STABLE ELEMENT TORQUING (Δω)
PROCESSOR
A15
CAGE CONTROL
GYRO SPIN CONTROL
CONTROL
DISCRETE I/O
A12
CONTROL
STATUS
PROM
A13
RAM
A14
DISPLAY DATA
TIMING
DISPLAY I/O
A11
DISPLAY DATA
DISPLAY SELECT
CONTROL-INDICATOR, ID-2112/WSN-2
1A2
DIGITAL DISPLAY INDICATOR
DS18
DIMMING CONTROL
A1
DSPL SEL SWITCH
S4
DSPL SEL NOG
EM LOG
LAT
OFF
PITCH
ROLL
TEST
S4
SYNCHRO SIGNAL AMPLIFIER AM-6047/WSN-2
1A8
TRUE HEADING (1X AND 36X) SINE/COSINE
ROLL (2X AND 36X) SINE/COSINE
INVERTER
A5
VITAL MODE INHIBIT
PITCH (2X AND 36X) SINE/COSINE
FROM DISCRETE I/O 1A3A12
CAGE CONTROL
HEADING AMPLIFIER (1X)
A1
HEADING AMPLIFIER (36X)
A2
ROLL-PITCH AMPLIFIER (ROLL)
A3
ROLL-PITCH AMPLIFIER (PITCH)
A4
HEADING (1X) SINE/COSINE
HEADING (36X) SINE/COSINE
ROLL (2X AND 36X) SINE/COSINE
PITCH (2X AND 36X) SINE/COSINE
TRANSFORMER ASSEMBLY
A7
NON-VITAL HEADING (36X) S1, S2, S3
NON-VITAL HEADING (1X) S1, S2, S3
VITAL HEADING (36X) S1, S2, S3
VITAL HEADING (1X) S1, S2, S3
ROLL (36X) S1, S2, S3
ROLL (2X) S1, S2, S3
PITCH (36X) S1, S2, S3
PITCH (2X) S1, S2, S3

160



# CHAPTER 3

## FUNCTIONAL DESCRIPTION

3-1. MAJOR FUNCTIONS. The Gyrocompass Set, Stabilized, AN/WSN-2, consists of five major assemblies or units in a single cabinet (1A1). These are the control-indicator (1A2), control-power supply (1A3), battery set (1A4), synchro signal amplifier (1A5), and inertial measuring unit (1A6). Together with the cabinet (1A1) and its mounted parts, these assemblies are interconnected to form a precision gyrocompass set (referred to as the equipment). The equipment operates in any of the following three modes, selectable at the control-indicator:

a. AUTO CAL (automatic calibration) mode

b. NAV (navigate) mode

c. DG (directional gyro) mode

3-2. SUPPORTING FUNCTIONS. The equipment is mechanized with several accessory functions which support its primary navigational functions. These are:

a. Latitude set

b. Data display

c. Reference speed selection

d. Panel illumination

e. Power supplies

f. BITE and alarms.

3-3. OVERALL FUNCTION. The primary function of the equipment is to produce precision analog dual speed roll, pitch, and heading signals for use by the ship's equipment (refer to figure 3-1). The equipment outputs are described in table 1-2. These outputs are available in all modes during normal operation. When the equipment is operating on the back-up power source (battery set, 1A4), only vital heading and its synchro reference are available.

a. Inputs. For its operation, the equipment requires from the ship certain electrical inputs. These are 115 VAC, synchro excitation voltages, and EM log data with its reference voltage. These inputs are detailed in Chapter 8, table 8-5 with identification of their input points and characteristics.

b. Modal Operation. Regardless of the operational mode selected, the equipment initiates a leveling sequence upon the application of power. See Chapter 2 for a description of the modes of operation. During the leveling sequence the stable element is north-seeking, thus establishing the reference for true heading computations. The bases for the equipment outputs are the angular output signals of the IMU (1A6). These are analog (resolver) signals representing:

(1) Sine of heading - both 1X and 36X speeds

(2) Cosine of heading - both 1X and 36X speeds

(3) Sine of roll angle - both 2X and 36X speeds

(4) Cosine of roll angle - both 2X and 36X speeds

(5) Sine of pitch angle - both 2X and 36X speeds

(6) Cosine of pitch angle - both 2X and 36X speeds

c. Signal Development. The roll, pitch, and heading resolvers, located in the IMU gimbal (1A6A2A1), are excited by 26v, 400 Hz when the gimbal is caged, or by 13v, 4.8 kHz during normal operation. Both resolver excitation levels are provided via servo amplifier 1A6A2A3. Each resolver has two outputs, which represent the sine and cosine of the angular position of its respective

rotor shaft. These outputs are sent back to the servo amplifier when the gimbal is caged. During normal operation, after the gimbal is uncaged, the resolver sine and cosine outputs are sent to resolver preamplifier 1A6A2A6. The roll and pitch sine and cosine signals from the resolver preamplifier are amplified, buffered, and converted to standard three line synchro data format by the synchro signal amplifier (1A5), then sent to the ship's equipment as S1, S2, and S3 synchro data. The heading sine and cosine signals from resolver preamplifier 1A6A2A6 are converted to true heading sine and cosine signals in true heading converters 1A3A8 (1X) and 1A3A9 (36X) before they are sent to the synchro signal amplifier (1A5). In synchro signal amplifier 1A5, the true heading sine and cosine data are, like the pitch and roll sine and cosine data, amplified, buffered, and converted to the standard three-line synchro data format. True heading subsequently is sent to the ship's equipment as S1, S2, and S3 synchro data. True heading sine and cosine outputs from the true heading converters are always referred to as the true heading signals, since they are always representative of the angular difference between the resolver outputs and the computed alpha angle. The alpha angle is the angular difference between the stable element Y axis and the true north, as computed by the processor (1A3A15). It should be noted that during the navigate (NAV) mode the alpha angle is maintained at zero, meaning that the stable element Y axis is maintained at true north. Consequently, true heading will be identical to the azimuth resolver output. The roll, pitch, and heading sine and cosine signals from resolver preamplifier 1A6A2A6 are also sent to A/D multiplexer 1A3A6. The A/D multiplexer sends the roll, pitch, and azimuth (heading) sine and cosine analog signals to A/D converter 1A3A7 where each sine/cosine pair is converted to the tangent of the respective angle, in digital format. The tangent values of the roll, pitch, and heading angles are sent to processor 1A3A15 for use in program computations and data updates.

**3-4. FUNCTIONAL DESCRIPTION.** The following paragraphs describe the operation of the equipment in its three major functional modes (refer to figure 3-2). The leveling sequence described in paragraph a, below, is a four-hour routine which provides for equipment leveling and initial calibration at equipment turnon. AUTO CAL mode, described in paragraph b, below, is a 24-hour routine that enables periodic equipment calibration during extended periods (greater than 90 days) of operation. Paragraphs c and d, below, describe the two operating modes (NAV and DG).

a. The Leveling Sequence. The stable element leveling sequence is initiated upon the application of power to the equipment (moving the MODE switch out of the POWER.OFF position). The major elements of the leveling sequence are: stable element caging, digital coarse leveling, fine leveling, gyrocompassing, and calibration.

(1) Stable Element Caging. At initialization and for ten seconds thereafter, gyro spin power is inhibited by the software and the stable element is caged. At the end of that 10-second delay, the gyros are energized with the high spin power. The software program allows sixty seconds for the gyros to gain speed then performs the gyro synchronization test. If the gyro synchronization test is passed, the program examines the output of the x accelerometer for minimum output (earth-level) and an up-to-temperature discrete. When the minimum output is sensed, the stable element is uncaged and placed under gyro control. Gyro spin power is then set to normal.

(2) Digital Coarse Leveling. At completion of the caging sequence all integrators and biases and the alpha (OC) angle signal are set to zero, and digital coarse leveling is initiated. Nominally, digital coarse leveling requires one minute. This time, however, may be lengthened by loop settling delays. Completion of digital coarse leveling is determined by the velocity error signals ($\Delta V_X$ and $\Delta V_Y$, figure 3-2). When the absolute values of the velocity error signals represent less than 0.5 ft/sec, digital coarse leveling is terminated and fine leveling is initiated.

(3) Fine Leveling. At the onset of fine leveling, as in digital coarse leveling, all integrators and biases and the OC angle signal are set to zero. Again, completion of the sequence is determined by the levels of the velocity error signals, $\Delta V_X$ and $\Delta V_Y$. When the absolute values of these signals represent less than 0.25 ft/sec (approximately six minutes) fine leveling is completed.

(4) Leveling Completion. At the end of the leveling sequence, the software calculates the $\alpha$ angle, establishes an initial value for latitude, and initializes the two direction cosines (pitch and roll angles). If a latitude entry was made at the onset of

or during the leveling sequence, that value will be the initial latitude. Otherwise, latitude is set to zero degrees.

(5) Gyrocompassing and Calibration. A four-step, timed procedure accomplishes the gyrocompassing and calibration sequence. The software estimates latitude if none was entered by the operator. In either case, latitude information will be updated at the end of the gyrocompassing and calibration sequence. At the completion of the gyrocompassing and calibration sequence the MODE, NAV indicator comes on and the MODE, ALIGN indicator goes off, indicating the alignment sequence is completed. Table 3-1 details the gyrocompassing and calibration sequence.

*Table 3-1. Gyrocompassing and Calibration Sequence*

| Step | Step name | Mechanization functions | Calibration functions | Time |
|---|---|---|---|---|
| | | Slew Y-Axis to -90° | None | 0 - 6 minutes |
| | | Settling Step | None | 2 minutes |
| 1 | East Gyrocompass | Coarse Gyrocompass | Minibias X-axis | 37 minutes |
| | | Fine Gyrocompass | Minibias X- and Z-axis and estimate latitude if no entry | 20 minutes |
| | | Slew Y-Axis to +90° | Accelerometer bias data | 6 minutes |
| | | Slew Settle | Estimate Y-accelerometer bias and remove platform tilt | 2 minutes |
| 2 | West Gyrocompass | Coarse Gyrocompass | Minibias X-axis | 27 minutes |
| | | Fine Gyrocompass | Minibias X-axis, minibias Z-axis, update latitude and compute X-axis bias | 20 minutes |
| | | Slew Y-Axis to 180° | None | 3 minutes |
| | | Slew Settle | None | 2 minutes |
| 3 | South Gyrocompass | Coarse Gyrocompass | Minibias Y-axis | 27 minutes |
| | | Fine Gyrocompass | Minibias Y- and Z-axis | 20 minutes |
| | | Slew Y-Axis to 0° | Bias accelerometers | 6 minutes |
| | | Slew Settle | Remove platform tilt | 2 minutes |
| 4 | North Gyrocompass | Coarse Gyrocompass | Minibias Y-axis | 27 minutes |
| | | Fine Gyrocompass | Minibias Y-axis, minibias Z-axis, update latitude and compute Y-axis bias | 15 minutes |

b. AUTO CAL Mode. Setting the MODE switch to AUTO CAL at any time after completion of the leveling sequence places the equipment into AUTO CAL mode. Mode selection is a function of the software, the MODE switch merely providing a ground discrete through the display I/O circuit card (1A3A11) to the processor (1A3A15). In AUTO CAL, heading is continuously slewed, completing 360 degrees every 24 hours.

(1) Pitch and Roll Angle. IMU resolver outputs representing pitch and roll angles are applied directly to the synchro signal amplifier (1A5). The synchro signal amplifier amplifies the input resolver information and transmits dual speed synchro information to the ship's equipment. Pitch and roll angle data are also applied to the A/D multiplexer (1A3A6).

(2) Heading. The IMU heading signals are applied to the true heading converters (1A3A8, 1A3A9). Also applied to the true heading converter is the alpha angle signal (which, in AUTO CAL mode, is set to a value representing 15 degrees/hour). These two quantities are combined in the true heading converter to develop true heading. The output of the true heading converter is sent to the synchro signal amplifier (1A5) for amplification and distribution to ship's equipment, and to the A/D multiplexer (1A3A6).

(3) Analog/Digital Data. The A/D multiplexer (1A3A6) develope both sine and cosine data for its input angular signals. These data are directed to the A/D converter, where they are used to develop digital quantities representing the tangent of the indicated angles. These tangent signals are multiplexed into the processor (1A3A15) for storage and subsequent use by the software program.

(4) Data Display. The digital display indicator, 1A2DS15, provides for local display of the quantities shown in table 3-2. The data for display are selected by the DSPL SEL switch, 1A2S4, and controlled by the software.

*Table 3-2. Data Display Parameters*

| DSPL SEL switch position | Data displayed | Range | Resolution | Remarks |
|---|---|---|---|---|
| LAT | Latitude | 0 to 90° | 1 minute | Sign of latitude is not displayed; degree and minute marks are displayed |
| EM LOG | LOG velocity | 0 to 99.9 knots | 0.1 knot | Leftmost digit is not used |
| HDG | True heading | 0 to 359.9° | 0.1° | |
| PITCH | Pitch | 0 to ±99.9° | 0.1° | Positive (bow down) sign is a blank |
| ROLL | Roll | 0 to ±99.9° | 0.1° | Positive (starboard up) sign is a blank |
| TEST | Test Pattern. The Program shall display all 0000's, 1111's through all 9999's. The pattern shall change approximately each second. | | | |

c. NAV Mode. NAV mode, the primary operating mode, is mechanized the same as the AUTO CAL mode (b, preceding) except that $\alpha$ angle is held at zero; thus, the equipment becomes a north-pointing gyrocompass.

d. DG Mode. When the equipment is operating in DG mode the stable element is damped by velocity signals and allowed to wander in azimuth. Earth rate correction is made by torquing the stable element in azimuth. The $\alpha$ angle signal is held constant and grid heading, rather than true heading, is sent to the ship's equipment. Otherwise, the equipment's function is the same as that for the AUTO CAL mode. The DG mode is used in latitudes above 85 degrees.

3-5. SUPPORTING FUNCTIONS. Major functions are supported by several supporting or subordinate functions. These are described in the following paragraphs:

a. Latitude Set (Figure 3-3). Entry of latitude data may be made during the leveling sequence, except during the north and south gyrocompassing phases, and at any time the system is NAV ready. Latitude data entered during leveling is stored for later use. Latitude entry should be made with the DSPL SEL switch (1A2S4) in the LAT position. Refer to figure 3-3 with the following functional description:

(1) Latitude Entry Enable. The equipment is prepared to receive a latitude entry when the ENTER LAT switch-indicator (1A2S8) is on. The software commands the ENTER LAT switch-indicator on when power is applied and when the position of the MODE switch (1A2S6) is changed. If the ENTER LAT switch-indicator is not on, entry can be enabled by pressing and releasing the ENTER LAT switch-indicator once. The equipment will then be enabled for one minute to receive a latitude entry.

(2) Latitude Entry. With the DSPL SEL switch (1A2S4) set to LAT, and the ENTER LAT switch-indicator (1A2S8) on, latitude entry is made by first setting the desired latitude (hemisphere, degrees, and minutes) in thumbwheel switch (1A2S7) then pressing and releasing the ENTER LAT switch-indicator (1A2S8). The ENTER LAT switch-indicator will go off and the selected latitude will be displayed on the digital display (1A2DS15). The closure of 1A2S8 provides a low (logic true) signal to the discrete I/O circuit card (1A3A12). The discrete I/O circuit card multiplexes the signal via a data bus into the processor data circuit (processor, 1A3A15; RAM, 1A3A14; and PROM, 1A3A13). The updated latitude information is then available for use as required by the equipment, and the processor transmits the new latitude to the digital display (1A2DS15) through the display I/O circuit card (1A3A11). The processor also commands the ENTER LAT switch-indicator off through the display I/O circuit card.

b. Data Display. Several elements of data are available for display on the control-indicator panel. The quantities available and the mechanization of the display circuit are shown on figure 3-4. The desired equipment parameter is selected by setting the DSPL SEL switch to the appropriate position. A discrete is routed through the display I/O circuit card (1A3A11) and multiplexed into the processor data circuit, enabling the software routine for data display. Also under software control, but not selectable, are the MODE, ALIGN indicator (1A2DS11) and MODE, NAV indicator (1A2DS12). When the equipment completes its alignment sequence, the software commands the MODE, NAV indicator (1A2DS12) on and the MODE, ALIGN indicator off.

c. Reference Speed Selection (Figure 3-5). The software controls the reference speed selection function (figure 3-5). The REF SP switch (1A2S5) is positioned by the operator to define to the software the operational mode required. Additionally, the REF SP switch provides a ground (via the dimming control circuit card, 1A2A1) to the REF SP, OVRD LOG indicator (1A2DS14), in the OVRD LOG position. This ground causes the REF SP, OVRD LOG indicator to come on when the OVRD LOG. The REF SP, OFF indicator is controlled by the processor, via the discrete I/O (1A3A12) and the dimming control (1A2A1). The EM log data input from the ship is changed from a synchro format to sine and cosine values by Scot-T transformers in the A/D multiplexer transformer (1A3A16). The EM log sine and cosine signals are selected by the A/D multiplexer (1A3A6) and converted to a tangent value, in digital format, by the A/D converter (1A3A7). The EM log tangent signal is applied to the processor (1A3A15). When the REF SP switch is set to OFF, the processor ignores the EM log inputs and permits the equipment to operate in the free-inertial state. When the REF SP switch is set to EM LOG, the processor commands

the software program to implement operation damped by the EM log velocity information. The EM log velocity information is monitored for reasonableness by the software program. When the software program determines that the EM log velocity information does not meet the reasonableness test, the processor will command the equipment to ignore the EM log data and operate in the free-inertial state. Additionally, the processor will initiate a reference speed off signal, which is sent via the discrete I/O (1A3A12) and dimming control (1A2A1) to the REF SP, OFF indicator, causing it to come on. The operator can elect to override the reasonableness test by setting the REF SP switch to OVRD LOG. When the REF SP switch is set to OVRD LOG, the processor disables the velocity monitor and commands the software program to use the EM log velocity information for damping purposes. The REF SP OFF indicator will go off, indicating that the processor has responded to the REF SP switch and the equipment is operating in the damped state. When the REF SP switch is set to DOCK, the processor commands the software program to use a zero reference velocity for damping instead of the EM log data input.

d. Panel Illumination (Figure 3-6). Two circuits control the level of illumination of control-indicator panel lighting and indicators. These circuits are illustrated functionally on figure 3-6.

(1) PANEL Illumination Control. PANEL potentiometer 1A2R2 is excited by plus and minus 15 VDC. The wiper is positioned to adjust a biasing level applied to the illumination sensing circuit in the dimming control (1A2A1). The output of the sensing circuit drives the dimming control amplifier, consisting of transistors 1A2Q1 and 1A2Q2 and related circuitry. The output of the dimming control amplifier is a variable level of voltage, above ground, determined by the position of the wiper of PANEL potentiometer 1A2R2. Figure 3-6 identifies the panel illumination elements controlled by the PANEL potentiometer.

(2) DISPLAY Illumination Control. Control-indicator status indicators and the digital display are controlled by DISPLAY potentiometer 1A2R1. DISPLAY potentiometer 1A2R1 provides a triggering level input (0 to +5v) to a controlled-width blanking pulse circuit, located on the dimming control (1A2A1). The blanking pulse is next applied to the indicator enabling control logic (also on the dimming control (1A2A1). When inputs to any of the controlled indicators (see figure 3-6) are true, an indicator on condition is commanded. The period of the blanking pulse, established by the position of the wiper of DISPLAY potentiometer 1A2R1, determines the level of illumination of the indicators. Indicators on the control-indicator that are controlled by the DISPLAY potentiometer are identified on figure 3-6.

e. Power Supplies (Figure 3-7). This functional description includes the uninterruptible backup power supply (backup power supply) and the normal operating power supplies. The backup power supply consists of the inverter (1A5A5) and inverter module (1A5A6) located in the synchro signal amplifier (1A5), relay 1A1K4 located in the cabinet (1A1), and the battery set (1A4). The normal operating power supply consists of the control monitor (1A3A1), battery charger (1A3A2), 5v regulator (1A3A3), 13v regulator (1A3A4), dc/dc module (1A3A5), and transformer-rectifier (1A3A17), all located in the control-power supply (1A3). The power supplies are described in paragraphs (1) through (5) below.

(1) Operation On 115 VAC Ship's Power. Three-phase 115 VAC power from the ship's power bus is routed via filter 1A1FL1 in the cabinet (1A1) to the control-indicator (1A2). Filter 1A1FL1 provides electromagnetic interference filtering for the three-phase power. The three-phase power is applied via the PWR circuit breaker (1A1CB2) in the control-indicator to the transformer-rectifier (1A3A17) which converts the three-phase 115 VAC to 35 VDC and 28 VDC (unregulated). The 35 VDC is routed to the battery charger (1A3A2). The 28 VDC (unregulated) is routed to the 5v regulator (1A3A3) and the 13v regulator (1A3A4). The battery charger (1A3A2) receives high and low voltage sense signals and a temperature sense voltage from the battery set (1A4). The battery charger (1A3A2) uses the temperature sense voltage to regulate the 35 VDC (input from transformer-rectifier 1A3A17), to provide a charging voltage to the battery contained in the battery set (1A4). This charging voltage is present as long as the 115 VAC ship's power is available and the equipment is turned on. The 28 VDC (unregulated) output from the transformer-rectifier (1A3A17) is applied to the 5v regulator (1A3A3) and the 13v regulator (1A3A4) as input power. The 5v regulator (1A3A3) reduces the 28 VDC to a regulated 5-volt level, which is distributed to all using circuit cards and assemblies in

the equipment. The 13v regulator (1A3A4) reduces the 28 VDC to a regulated 13-volt level, which provides power to the dc/dc module (1A3A5). The 13v regulator (1A3A4) is turned on (by control-monitor 1A3A1) before the 5v regulator (1A3A3) to allow the dc/dc module (1A3A5) and the equipment to stabilize prior to the distribution of 5 VDC. The dc/dc module (1A3A5) provides output voltage of +28v, -28v, +15v, -15v, +20v floating, +50v floating and +50v to using circuits in the equipment. Single-phase 115 VAC power from the ship's power bus is routed via filter 1A1FL2 in the cabinet (1A1) to the control-indicator (1A2). Filter 1A1FL2 provides electromagnetic interference filtering. The single-phase 115 VAC is applied via the SYN REF circuit breaker (1A2CB1) in the control-indicator (1A2) and relay 1A1K4 in the cabinet (1A1), to provide power for the equipment blowers and a vital heading reference output to the ship's equipment.

(2) Operation On Backup (Battery) Power. The equipment will switch to operation on battery power when the three-phase 115 VAC or the single-phase 115 VAC power from the ship's power bus drops out completely, loses a phase, or exceeds prescribed voltage or frequency tolerances. Single-phase 115 VAC and three-phase 115 VAC outputs from the transformer-rectifier (1A3A17) in the control-power supply (1A3) are applied to the control-indicator (1A3A1). When these outputs are lost or exceed the prescribed tolerances, the dc relay control output from the control-monitor (1A3A1) commands the transformer-rectifier (1A3A17) to switch from the three-phase 115 VAC input to the 24 VDC input from the battery set (1A4). Also, the inverter control output from the control-monitor (1A3A1) enables the inverter (1A5A5) and the inverter module (1A5A6) to produce 115 VAC, which is applied to relay 1A1K4 in the cabinet (1A1). To complete the transfer to operation on battery power, the control-monitor (1A3A1) sends the ac relay on command to enable relay 1A1K4 to switch from the single-phase 115 VAC power input from the ship's power bus to the 115 VAC input from the inverter (1A5A5)/inverter module (1A5A6). Refer to table 1-2 for the frequency and voltage level tolerances of the monitored power inputs.

(3) On-Off Control. The equipment is turned on and off by logic circuits contained in the control-monitor (1A3A1) located in the control-power supply (1A3). The on-off control in the control-monitor (1A3A1) is initiated by MODE switch (1A2S6) in the control-indicator (1A2). When the MODE switch is set to any position other than POWER OFF, an on-off control signal to the control-monitor (1A3A1) enables the on-off control outputs to the 5v regulator (1A3A3) 13v regulator (1A3A4), and the dc/dc module (1A3A5). The 13v regulator (1A3A4) is turned on slightly ahead of the 5v regulator (1A3A3). Additionally, a battery relay control signal is sent from the control-monitor (1A3A1) to the transformer-rectifier (1A3A17). The battery relay control signal energizes a relay in the transformer-rectifier (1A3A17). When this relay is energized, it connects the 24 VDC from the battery to the input of the transformer-rectifier (1A3A17). This ensures that the equipment will not initially turn on unless the three-phase 115 VAC and the single-phase 115 VAC from the ship's power are present and are within specified voltage and frequency tolerances. On-off commands are also sent from the control-monitor (1A3A1) to the equipment. The control-monitor (1A3A1) will automatically turn the power supplies off when initiated by the automatic power shutdown condition (paragraph (4), following.

(4) Automatic Power Shutdown. Certain conditions existing in the equipment will cause the control-monitor (1A3A1) to automatically turn the equipment off. When any of the conditions described in paragraph (a) through (d) below occur, the control-monitor (1A3A1) automatically turns the equipment off just as if the MODE switch (1A2S6) were set to the POWER OFF position, with one exception. When an automatic power shutdown occurs, BITE signals are applied to the IMU I/O (1A3A10) in the control-power supply (1A3) to enable the proper fault indicators and alarms:

(a) Overtemperature

(b) Power supply fault

(c) IMU (A6) fault (servo amplifier 1A6A2A3 or gyro spin (1A6A2A5 failure)

(d) Battery undervoltage, where operating on battery

(5) BITE. BITE circuits within the control-monitor (1A3A1) continuously monitor the 5v regulator (1A3A3), 13v regulator (1A3A4), dc/dc

module (1A3A5), and transformer-rectifier (1A3A17) outputs for overvoltage and undervoltage conditions. The control-monitor (1A3A1) also monitors the frequency and voltage of the three-phase and single-phase 115 VAC inputs and the power supply temperature. When an out-of-tolerance condition or fault occurs, BITE fault signals are outputted to the BITE (paragraph f below).

f. Built-In-Test Equipment (BITE) and Alarms. The BITE provides four types of built-in tests. These are hardwired, software built-in test, software initiated BITE, and software monitored BITE. The hardwired BITE consists of test logic that is wired directly to the fault circuits. Fault signals that enable the automatic shutdown sequence are hardwired. The software built-in tests are tests that are controlled by the processor (1A3A15), rather than by hardwired logic circuits. Software built-in tests include a checksum test for the PROM (1A3A13), a verification test for the RAM (1A3A14), and an arithmetic test for the processor (1A3A15). The software initiated BITE consists of hardwired logic circuits that are activated by the processor (1A3A15). These include wraparound tests for the A/D converter (1A3A7), IMU I/O (1A3A10) display I/O (1A3A11), and the discrete I/O (1A3A12). The software monitored BITE circuits are not wired directly to fault circuits. Instead, the monitored parameters are compared to other parameters known to the software. If the monitored parameters are determined to be invalid, the appropriate fault indicator is enabled and, if the fault warrants, the equipment is shut down. Software monitored BITE monitors the quantizer (1A6A2A2), servo amplifier (1A6A2A3), and the gyro spin (1A6A2A5) circuit cards. When any fault is detected by the BITE, the ALARM indicator on the control-indicator (1A2) comes on (as does the appropriate fault indicator) and the malfunction summary alarm signal to the ship's equipment is enabled. If the ship's primary power input is lost or exceeds the specified tolerances (refer to table 1-2), the BITE will automatically transfer the equipment to battery operation and enable the alarms. The BITE and alarm circuits are described in paragraphs (1) through (7) below.

(1) FAULT, AIR (Figure 3-8). If an overtemperature condition occurs in the power supply section of the control-power supply (1A3), the synchro signal amplifier (1A5), or the IMU (1A6), an overtemperature signal will be sent to the BITE in the IMU I/O (1A3A10). Fault summary logic in the IMU I/O (1A3A10) will then send a fault, air set signal to the control-indicator (1A2). The fault air set signal will set the FAULT, AIR indicator (1A2DS7). The IMU I/O (1A3A10) sends an alarm signal to the control-indicator (1A2) and an alarm relay on signal to the alarm relay (1A1K1; paragraph (7), below). Additionally, an overtemperature no-go signal is sent to the control-monitor (1A3A1), which enables the automatic power shutdown sequence (paragraph (4), below).

(2) FAULT, DI (Figure 3-8). The processor (1A3A15) monitors the control signals from the control-indicator (1A2) via the discrete I/O (1A3A12). When a failure of the control-indicator (1A2) results in erroneous control outputs, the processor (1A3A15) detects a fault and enables a fault, DI set signal (via the discrete I/O, 1A3A12) to the FAULT, DI indicator (1A2DS2) on the control-indicator (1A2) and to the IMU I/O (1A3A10). The fault, DI set signal to the IMU I/O (1A3A10) enables the alarm (paragraph (7) below).

(3) FAULT, CTR (Figure 3-9). Circuit cards in the control section of the control-power supply (1A3) are monitored and tested by the processor (1A3A15). When a circuit card faults, BITE fail discrete lines to the IMU I/O (1A3A10) are enabled to set the proper fault indicators (1A3A10DS1 through 1A3A10DS6) on the IMU I/O. Refer to table 5-8 to identify which fault indicators set when each circuit card faults. The BITE fail discrete lines are also applied to the fault summary logic in the IMU I/O (1A3A10). When any fault in the control section of the control-power supply (1A3) is detected, the BITE fail discretes to the summary logic in the IMU I/O (1A3A10) enable the fault, control set signal to the control-indicator (1A2). The fault, control set signal causes the FAULT, CTR indicator (1A2DS3) on the control-indicator (1A2) to set. Additionally, the IMU I/O sends an alarm signal to the control-indicator (1A2) and an alarm relay-on signal to the alarm relay (1A1K1; paragraph (7), below). The A/D converter (1A3A7) is periodically tested by the BITE, under the control of the processor (1A3A15). To perform this test, the A/D multiplexer (1A3A6) is switched to the test mode by command of the processor (1A3A15). In the test mode the A/D multiplexer sends a fixed test angle to the A/D converter (1A3A7). If the A/D converter (1A3A7) fails to pass the correct angle a BIT

fail signal is enabled and the proper BITE fail discretes are sent to the IMU I/O (1A2A10) to set the proper combination of fault indicators (1A2DS2 and 1A2DS3) on the IMU I/O (1A3A10). The true heading converters (1A3A8 and 1A3A9) are tested periodically by the processor (1A3A15) by comparing the tangent output of each true heading converter against the other. This is possible since there is a constant 36 to 1 ratio existing between the two true heading converters (1A3A8 and 1A3A9). The processor (1A3A15) periodically tests itself by performing a fixed arithmetic test.

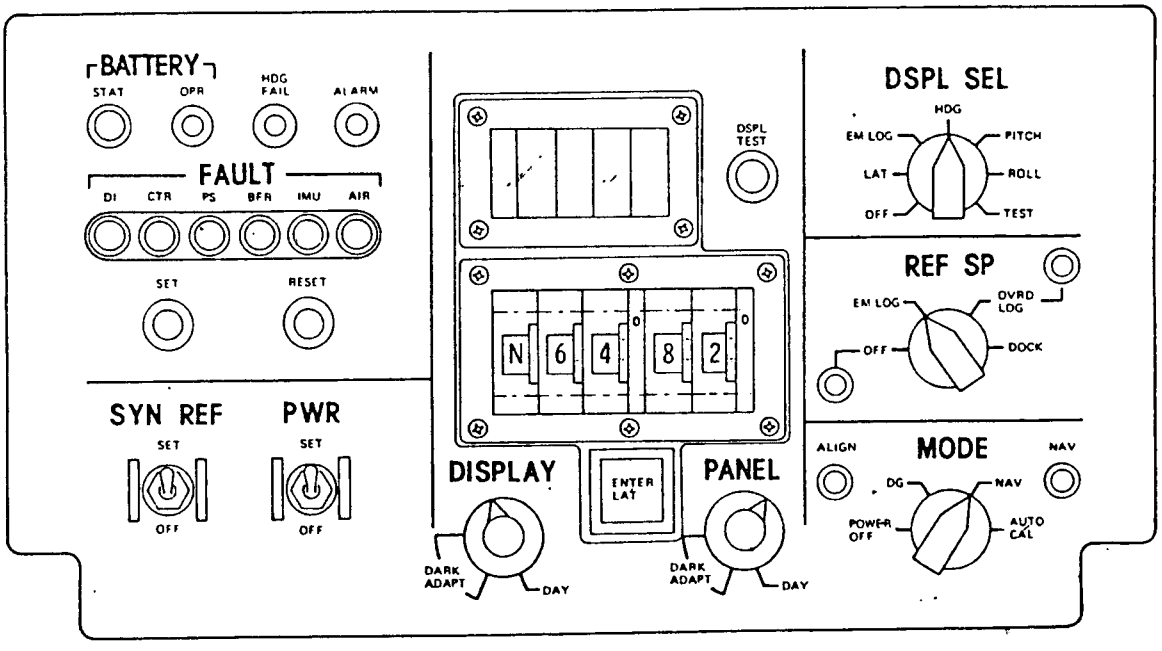
(4) FAULT, PS; BATTERY, STAT; and BATTERY, OPR (Figure 3-10). The battery set (1A4) and the circuit cards contained in the power supply section of the control-power supply (1A3) are monitored by hardwired BITE. BITE logic circuits contained in the control-monitor (1A3A1) continuously monitor the 5v regulator (1A3A3), 13v regulator (1A3A4), and the dc/dc module (1A3A5) for overvoltage and undervoltage conditions. The BITE logic circuits in the control-monitor (1A3A1) also monitor the battery charger (1A3A2) and the battery set (1A4) for an overvoltage and undervoltage condition. If the battery charger (1A3A2) indicates an undervoltage condition the control-monitor (1A3A1) sends a battery status set signal to the control-indicator (1A2), causing the BATTERY, STAT indicator (1A2DS1) to set. An overvoltage condition in the battery charger (1A3A2), 5v regulator (1A3A3), 13v regulator (1A3A4), or dc/dc module (1A3A5) will set the fault indicator on the faulty circuit card and enable the control-monitor (1A3A1) to send the fault, power supply set signal to the control-indicator (1A2). The enabled fault, power supply set signal will cause the FAULT, PS indicator (1A2DS4) on the control-indicator (1A2) to set. Additionally, the control-monitor (1A3A1) will turn off the 5v regulator (1A3A3), 13v regulator (1A3A4), and the dc/dc module (1A3A5) when an overvoltage condition is sensed. However, the fault indicators will have sufficient time to set before the power supply is turned off. An equipment overtemperature condition (see figure 3-8) or a failure of the servo amplifier (1A6A2A3) or gyro spin (1A6A2A5) (see figure 3-12) will initiate no-go commands to the control-monitor (1A3A1) which also will shut down the power supply. The control-monitor (1A3A1) also senses the voltage and frequency of the three-phase 115 vac power and synchro reference inputs at the transformer-rectifier (1A3A17). If the three-phase input is lost or exceeds specified tolerances, the control-monitor (1A3A1) will switch the equipment to battery operation and enable the battery operate signal to the control-indicator (1A2). The battery operate signal causes the BATTERY, OPR indicator (1A2DS8) to come on. The battery, status set signal and the battery operate signal are also sent to the IMU I/O (1A3A10, figure 3-13) to generate alarms.

(5) FAULT, BFR and HDG FAIL (Figure 3-11). Circuit cards and assemblies in the synchro signal amplifier (1A5) are monitored by hardwired BITE. The 1X heading amplifier (1A5A1), 36X heading amplifier (1A5A2), roll amplifier (1A5A3), pitch amplifier (1A5A4), and inverter (1A5A5) each has a fault indicator. The fault indicator on the inverter sets when the inverter (1A5A5) or the inverter module (1A5A6) fail. A fault in any of these circuit cards or module will set the fault indicator located on the respective faulty circuit card and enable a BITE fail signal to fault summary logic contained in the inverter (1A5A5). When the fault summary logic receives a BITE fail signal, a fault, buffer set signal is set via the IMU I/O (1A3A10) to the FAULT, BFR indicator (1A2DS5) on the control-indicator (1A2), causing it to set. If either of the heading amplifiers (1A5A1 or 1A5A2) faults during battery operation, the inverter (1A5A5) will send a vital heading fail signal to light the HDG FAIL indicator (1A2DS9) on the control-indicator (1A2). If the inverter (1A5A5) or inverter module (1A5A6) fail during battery operation, the inverter (1A5A5) sends a buffer fail power supply signal to the control-monitor (1A3A1) to command a power shutdown. A failure of either the servo amplifier (1A6A3) or the gyro spin (1A6A5) located in the IMU (1A6) enables a no-go signal to the control-monitor (1A3A1), causing a power shutdown. A failure of either the servo amplifier (1A6A3) or the gyro spin (1A6A5) also enables a heading fail signal from the control-monitor (1A3A1) to the control-indicator (1A2). This signal will also light the HDG FAIL indicator (1A2DS9).

(6) FAULT, IMU (Figure 3-12). Circuit cards and assemblies in the IMU (1A6) are tested by a combination of hardwired and software monitored BITE. When either faults, the servo amplifier (1A6A3) or gyro spin (1A6A5) circuit card will enable a hardwired BITE fail signal. The gyro spin circuit card (1A6A5) also is tested under control of the processor (1A3A15). The remaining circuit

cards and assemblies in the IMU are tested by the processor (1A3A15). When the processor (1A3A15) detects a fault, discrete signals are sent via the discrete I/O (1A3A2) to four fault indicators (1A6DS1 through 1A6DS4), located on the front of the IMU (1A6). These discrete signals set the proper fault indicators (refer to table 5-9). A fault, IMU set signal is also sent via the discrete I/O (1A3A12) to the control-indicator (1A2) to set the FAULT, IMU indicator (1A2DS6). If the stable element (1A6A2A1A7), which contains the gyros and accelerometers, overheats, the processor (1A3A15) will send a stable element overtemperature signal to the IMU I/O (1A3A10, refer to figure 3-8 and paragraph (1) above).

(7) ALARMS (Figure 3-13). The IMU I/O circuit card (1A3A10), in the control-power supply (1A3), contains alarm summary logic for the BITE circuits. The alarm summary logic receives hardware-detected fault signals from the BITE circuits (paragraphs (1) through (6) above). It also receives alarm signals generated by processor (1A3A15) detected faults (via the discrete I/O, 1A3A12), and from the transformer-rectifier (1A3A17) (via the control-monitor, 1A3A1). Any one or all of these signals will enable the IMU I/O (1A3A10) alarm output to the control-indicator (1A2), causing the ALARM indicator (1A2DS10) to come on. Any one or all of these signals will also enable the IMU I/O (1A3A10) to send the alarm relay on signal to the alarm relay (1A1K1). The alarm relay on signal causes the normally energized alarm relay (1A1K1) to deenergize. When the alarm relay (1A1K1) deenergizes, the malfunction summary alarm is sent to ship's equipment. When the three-phase power or synchro reference input (sensed at transformer-rectifier 1A3A17) is lost or exceeds specified tolerances (refer to table 1-2), the control-monitor (1A3A1) switches equipment operation to battery power (refer to paragraph (4), above) and sends an alarm signal to the IMU I/O (1A3A10). The alarm signal causes the IMU I/O (1A3A10) to send the on battery relay on signal to the on-battery relay (1A1K2). The on-battery relay-on signal causes the on battery relay (1A1K2) to energize. When the normally deenergized on battery relay (1A1K2) energizes, the on-battery alarm is supplied to the ship's equipment.




CONTROL-INDICATOR FRONT PANEL 1-3-1

# ARL PLOTTING TABLES

DISTANCE DRIVE:
Impulses from the LOG cause the soleniod-operated armature to release spokes of the Escapement pinwheel, which is rotated under the influence of a coiled spring and driven along a threaded shaft. An insulated thimble carried by the pinwheel, controls spring contacts which in turn control thr MAIN DRIVE MOTOR over a range of three speeds. The motor drives the inner wheel of a resolver and provides a variable recentering drive to the pinwheel, assembly through the Logarithmic cones. It is possible to offset for Log percentage error.

COMPASS DRIVE:
The input from the compass drives an 'M' type motor to offset one side of a differential. The output of the differential displaces a cam which in turn makes contacts to control a Compass Chaser motor over a range of two speeds in either direction. The motor in running positions the outer wheel of the resolver for ships head and at the same time produces a recentering drive into the differential.

RESOLVER:
Has two gear wheels, one half the diameter of the other. The smaller is driven for distance and is rotated around the inner circumference of the larger gear which is positioned for ship's head. A point on the circumference of the inner wheel will be found to trace a straight line across the diameter of the outer, and the direction of this line will be determined by the ship's head set on the outer. In practice a stud isfitted at this point which runs in two sliders set in quadrature. The sliders drive racks and pinions to transmit away the sine and cosine increments of the course and distance made good. (ie: N/S and E/W components).

180° REVERSABLE CLUTCHES:
Are fitted in the N/S and E/W output drives to remove unwanted increments of the rack movements to ensure a uni-directional drive, and to ensure that the output is in the correct direction by reversing there function at the requisite cardinal points.

OUTPUT DRIVES:
The N/S and E/W rotations each pass through a gear box for scale changing and are protected by a Safety Spring Clutch which ruptures if an output drive reaches it's mechanical limit. A cross frame carring a point light source denotes ship's position. This frame is driven bodily by the E/W drive and the light is moved along the frame by the N/S drive.

POWER SUPPLY:
24 Volts D.C.

LINING UP THE RESOLVER:
(1) Break the GYRO switch.
(2) Engage locking bar with the differential cam.
(3) Rotate handwheel to line resolver to ship's head
(4) Disengage locking bar.
(5) Make the GYRO switch.

CLOCK DRIVE:
When the ship's log is out of action it is possible to simulate the ship's speed through the water using a make and break driven by a clock to pulse the pin wheel's operating soleniod. (wind the clock and put LOG/OFF/CLOCK switch to CLOCK). As the clock gives ½ second impulses which are equivalent to 18 knots it is necessary to offset the scale setting to simulate actual speed. This is achieved by setting a scale figure of actual ship's speed against the required scale instead of the normal arrow.

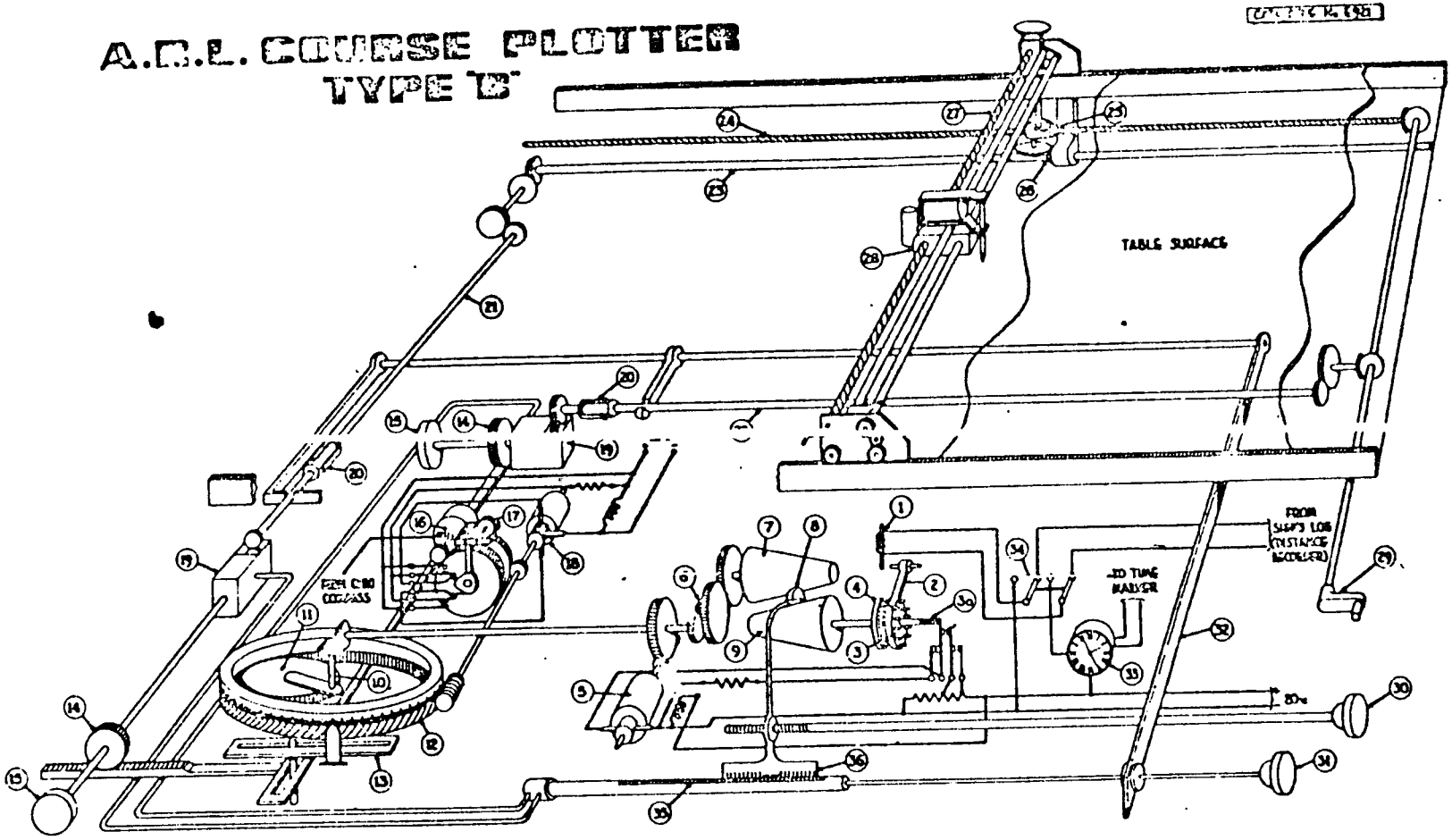
ARL PLOTTING TABLE

The plotting table provides a means of plotting own ships course and distance run. Electrical impulses from the ships log and transmissions from the compass are converted into mechanical drives proportional to ships movement in North/South and East/West directions. These drives position a lamp unit which projects a spot of light onto the underside of the plotting surface. By plotting the spot of light, a record of ships course and distance travelled is obtained.

OPERATION

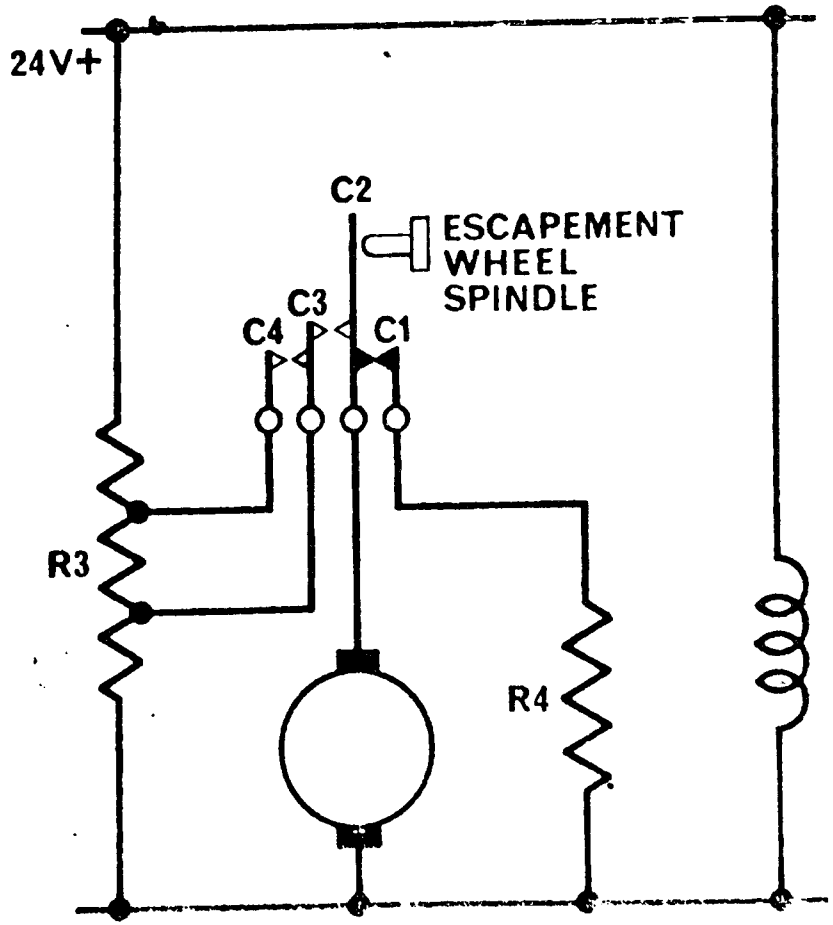
Impulses from the ships log energise a relay (1). The relay operates an armature (2) raising it when energised. At each movement of the armature, either up or down, the Spoked Escapement Wheel (3) is released one spoke. As the wheel is released it feeds forward on the screw thread and the Thimble (3A) closes the contact and operates the circuit for the Main Drive Motor (5), which rotates and drives a vertical shaft (10) in the Resolver. The Main Drive Motor also drives through gearing (6) the cones (7,8,9).
As the Lower cone rotates, it tends to withdraw the spoked wheel and the thimble away from the contact. In this way, the Main Drive motors revolutions are controlled by the impulses from the ships log.
The resolver divides the rotations of the central vertical shaft (10) into the N/S and E/W components and the unwanted increment of each output is removed in a reversable ball clutch (14). The proportion of these two components is governed by ships head.
A Sperry repeater motor (16) displacing a Hunter (17) which operates some contacts which control the Compass Chaser Motor (18).
This motor rotates the outer ring (12) of the resolver and also recentres the Hunter. The Sperry Motor runs for course changes and so the resolver outer ring is kept lined up with ships head. The N/S and E/W rotations each pass through a gearbox (19) to allow for scale changing and are protected by a Safety Spring Clutch (20) which ruptures if an output drive reaches its mechanical limit.
various drives and leadscrews finally move the cross frame to and fro for E/W movements via the nut (25), and moves the light carrage (28) backwards and forwards for N/S drives via the bevel gears(26) and the associated leadscrew (24) and (27). If for any reason the ships log cannot br used, the clock (33) may be used, it produces steady impulses for the relay and different estimated speeds may be represented by setting the scale (36), this interposes the requisite gearing between the Main Drive Motor and the Lower cone. The idler wheel must not be moved unless the cones are rotating, or flats will develope on the wheel and the cones will become scored.

# A.D.L. COURSE PLOTTER
## TYPE 'B'

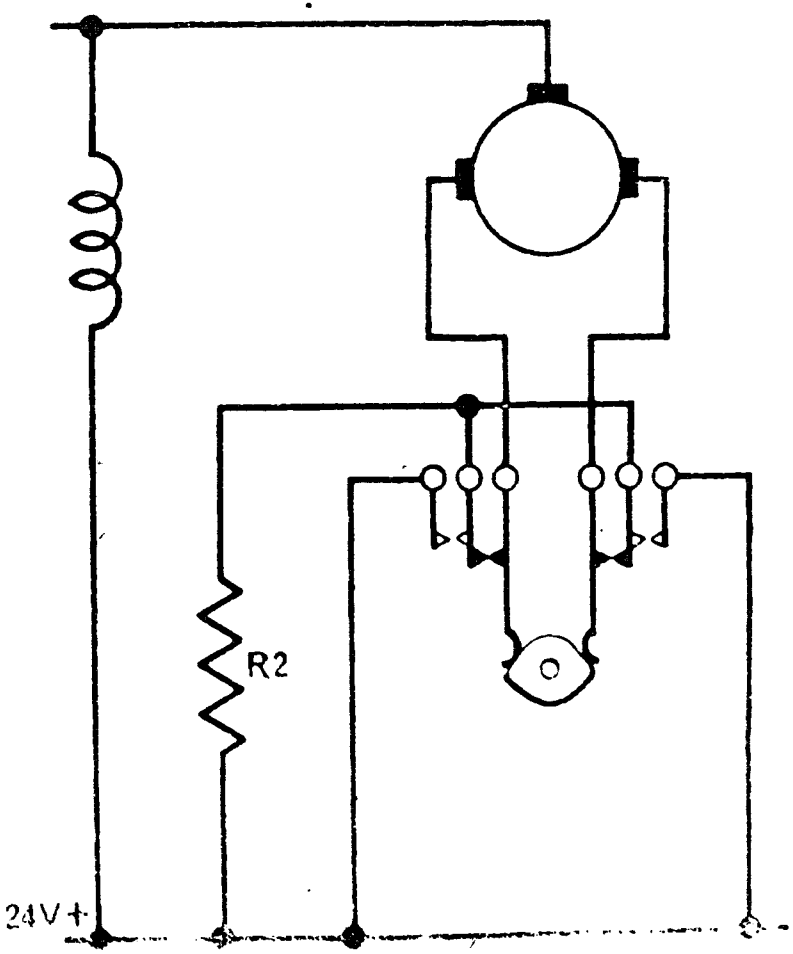


# A.R.L. PLOTTING TABLE

## MAIN DRIVE MOTOR CIRCUIT




## COMPASS CHASER MOTOR CIRCUIT




173

# HEWLETT PACKARD TAPE RECORDER MODEL 3968A

## TAPE SERVO OPERATION

Tapr servo operation is used to play back with maximum accuracy of recorded data. The process involves using the same reference frequency to control the servo system during play back that was used when the recording was made. One data channel and one tape track are required for tape servo operations, which are conducted using FM PCA'S on Submarines.

### FM TAPE SERVO OPERATION

(1) Tape servo operation using a FM PCA is conducted as follows:
(2) Channel 5 is used on submarines because only this channel can be used for COMBINED FLUTTER COMP/TAPE SERVO OPERATION.
(3) Remove the front panel.
(4) Remove the FM data PCA in channel 5. It is to be used to record the reference frequency.
(5) Make the following jumper connections on the tape servo FM data PCA. [see figure 3-5]

DUBBING INPUT SELECTOR: Pin C to Pin D.
DUBBING OUTPUT SELECTOR: Pin C to Pin D1.
TAPE SERVO SELECTOR: PIN C to PIN TS.

(6) Reinstall the tape servo FM data PCA and reinstall front panel. Switch to operate on channel 5.
(7) Connect a coaxial cable from the INTERNAL REF OUTPUT connector on the rear panel to the INPUT connector of the FM PCA in channel 5.
(8) Check position of INTERNAL/EXTERNAL switch on rear panel. Should be in the internal (outward) position.
(9) Install a reel of degaussed recording tape.
(10) Set the recorder POWER switch to ON.
(11) Recorder is now in the STOP mode.
(12) Switch to OPERATE on FM channel 5.

NOTE

INPUT and OUTPUT LEVEL adjustments are not required on an FM PCA which is being used for Tape Servo.

(13) Adjust the input and output levels on all FM PCA'S which are used for recording data as described in paragraphs 3-16 and 3-18 of the HAND BOOK.
(14) Adjust the input levels on all DIRECT PCA'S in the recorder which are used for recording data as described in paragraph 3-23 of the HAND BOOK.
(15) Set the front panel TACH-TAPE switch to TACH.
(16) Select the desired tape speed [ 7½ ].
(17) Press forward RECORD.
(18) The recorded tape can now be reproduced in Tape Servo Mode. Connect a coaxial cable between the TAPE SERVO INPUT connector on the rear panel and the OUTPUT connector of CHANNEL 5.
(19) Rewind the tape.
(20) Switch the SERVO switch to Tape.
(21) Press forward PLAY.

NOTE

The front panel TAPE indicator will light when the tape is moving at the selected speed.

(22) Adjust the output levels on all DIRECT PCA's which are used for data reproduction. Use the procedures listed in paragraph 3-25 of the HAND BOOK.

NOTE

Switch the FLUTTER COMP switch OFF to calibrate the FM data channels, then switch ON when ready to play back.

175

WEES 190/83

# MX 1122 RAN

# SATELLITE NAVIGATOR

| | | |
|---|---|---|
| HANDBOOKS: | VOL 1 | TEM 5825 - 0014 - 1 |
| | VOL 2 | TEM 5825 - 0014 - 2 |
| | VOL 3 | TEM 5825 - 0014 - 3 |

# TRANSIT SATELLITE NAVIGATION SYSTEM

The ideal navigational system would be one that gave the user a positional fix for 24 hours of the day regardless of the position of the user. Research is being conducted on a Global Position System, NAVSTAR, which will fill this requirement but this is not due to become operational until towards the end of the century.

The Transit system attempts to solve the problem by using six satellites in polar orbits. The satellite fixes are used to update a dead reckoned position calculated from log and gyro-compass inputs.

This system provides a combination of capabilities not obtainable with other systems in use. These are:

(1) Total global coverage.

(2) All weather operation.

(3) Accuracy approaching that of short range radio systems.

(4) High dependability.

(5) Freedom from propagation irregularities.

The accuracy of the satellite fix is in the order of 0.05 nautical miles plus 0.2 nautical miles per knot of speed error.

The Transit system grew out of the marrying of a vital need and newly available technology. The need was to have accurate position updates for the inertial navigation equipment aboard the Polaris Submarines. The new technology came into being through the discovery of the substantial Doppler frequency shift of radio signals transmitted from the first artificial earth satellite - Sputnick I.

This interest led to the development of mathematical formulae which enabled the entire satellite orbit to be determined, by careful Doppler measurement, from a single ground tracking station.

It was found, by inverting the process, that a Ship's position could be determined with Doppler measurement from a satellite with an accurately known orbit. Thus the Transit satellites transmit a phase modulated signal, representative of their orbital positions which the Ship receives for decoding. By integrating the received decoded message, Doppler shift and Ship's velocity in a microprocessor, exact geographical position is determined.

The system became operational in 1964 and commercially available in 1967. Presently there are 6 satellites in use with circular polar orbits, about 1075 kilometres high, circling the earth every 107 minutes.

This constellation of orbits forms a "birdcage" within which the earth rotates, carrying us past each orbit in turn.

Whenever a satellite passes above the horizon, the Ship has the opportunity to obtain a position fix. The average time interval between fixes with the existing 6 satellites varies from 35 to 100 minutes depending on the latitude of the receiver. However, this period may be extended considerably in certain areas around the equator.

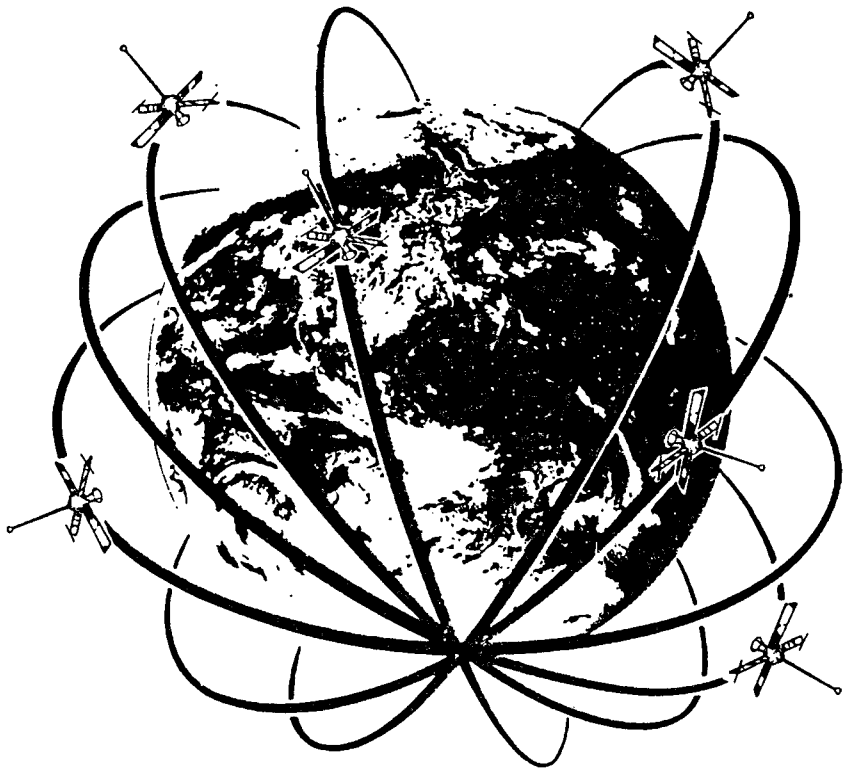


Figure 1

Each satellite is a self-contained navigation beacon which transmits two very stable frequencies (150 & 400 MHz), timing marks and a navigation message.

This positional information, transmitted by the satellites, is updated every 12 hours. The update information is acquired from tracking stations that receive the 150 and 400 MHz satellite signals and measure the Doppler frequency shift, caused by the satellite's motion, and record the Doppler frequency as a function of time. This information is then used to determine each satellite's orbit and project each orbit many hours into the future. The resultant information is then injected back into the appropriate satellite by one of the two injection stations.

Unlike earth based radio-location systems which determine position by nearly simultaneous measurements of signals from several fixed transmitters, Transit measurements are with respect to sequential positions of the satellite as it passes.

This process requires from 10 to 16 minutes during which time the satellite will have travelled between 4400 to 7000 kilometres providing an excellent base line.

Because these measurements are not instantaneous, ship's motion during the pass and the satellite's motion relative to the earth must be considered in the fix calculations. As these calculations are both complex and extensive, a small digital computer is required to give the speed and accuracy required for an accurate fix.

## ERROR

There are two principal components of error in the system. The first error component, approximately 0.05 nautical mile, consists of the inherent system error, the second is introduced by unknown ship's motion during the satellite pass. As a rule of thumb, the second error is approximately 0.2 nautical mile of positional error for each knot of unknown ship's velocity.

## NAVIGATION BETWEEN FIXES

Between fixes the computer automatically dead-reckons based on inputs of speed and heading. These inputs are either keyed in by the operator or from the ship's log and gyro.

After a satellite pass and the new position has been computed, latitude and longitude adjustments are applied, thus correcting for the accumulated dead reckoning error.

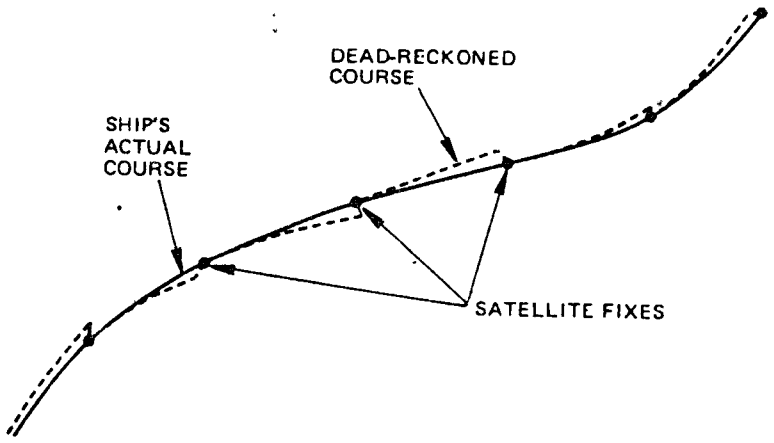



Figure 2 - Dead Reckoning Error is Calculated by Each Satellite Position Fix Update

## SATELLITE DESCRIPTION

### PHYSICAL

The satellite has 4 solar panels for power generation and uses a "lamp-shade antenna" which is always pointed toward earth by the use of a

gravity gradient stabilization boom. Hysteresis rods on the solar panels eliminate sway caused by the natural tendency of an orbital body to align earth's magnetic field.

ELECTRONIC

The satellites transmit two frequencies 399.968 MHz and 149.988 MHz. Both these frequencies are derived by direct multiplication of a reference frequency output and hence are very stable, changing no more than 1 in 10" during a satellite pass.

The reference oscillator output is also divided in frequency to drive the memory system. In this way the stored navigation information is read out and encoded by phase modulation onto both the 150 and 400 MHz signals at a constant and carefully controlled rate. Thus, the transmitted signals provide not only a constant reference frequency and a navigation message but also timing signals, hence the navigation message is controlled to begin and to end at the instant of every even minute. An updated navigation message and time corrections are obtained periodically from the ground by way of the satellite's injection receiver. The navigation correction data is stored in the memory and is applied in steps of 9.6 microseconds each.

Each binary bit of the message is transmitted by phase modulation of the 150 MHz signals. The following diagram illustrates the modulation format for a binary "one", and a binary "zero" is transmitted with the inverse pattern.

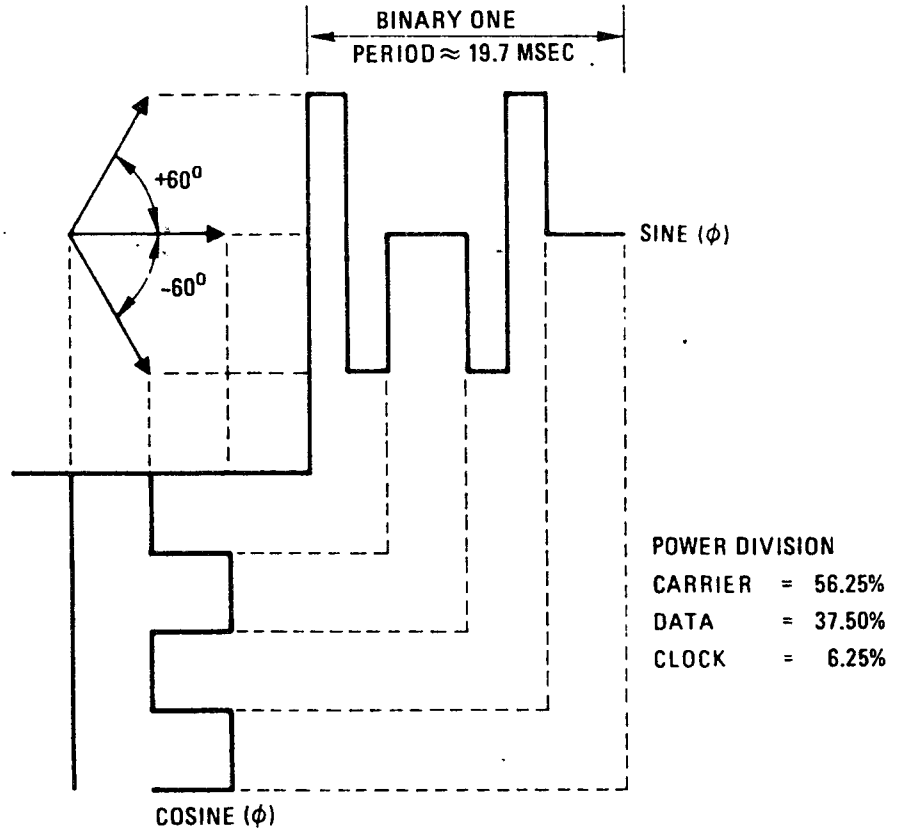



Figure 3 - Transit Data Phase Modulation

This doublet pattern is derived by either retarding or advancing the transmitted signal by 60° and hence furnishes a clock signal at twice the bit rate. This clock signal is used to synchronise the receiving equipment with the message data.

MODULATION FORMAT

During every two minute interval the satellite transmits a message consisting of 6103 binary bits of data organised into 6 columns and 26 lines of 39 bit words, plus a final 19 bits.

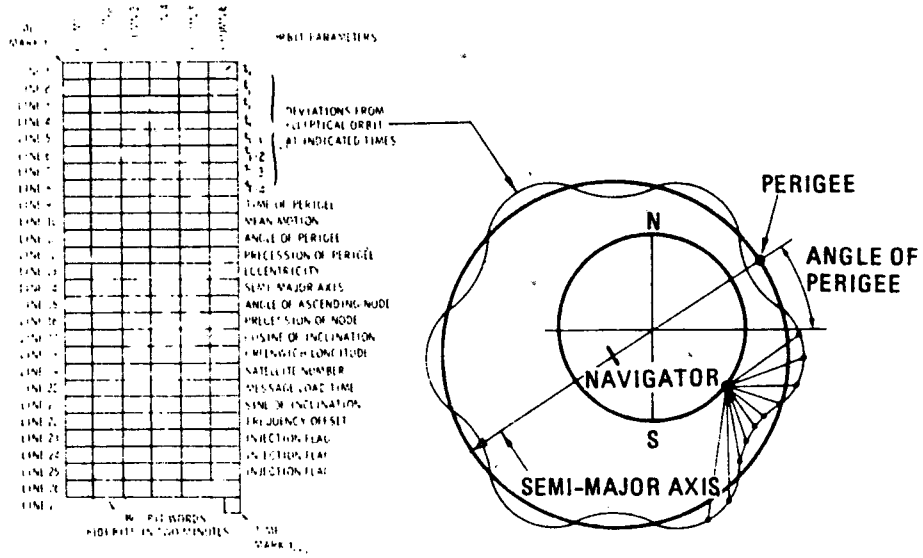



Figure 4 - Satellite Message Describes Orbital Position

This message begins and ends at the instant of the even minute. The final 25 bits of each message form a synchronisation word that identifies the time mark and the start of the next 2 minute message. By recognising this word, the shipborne receiver establishes time synchronisation and thereafter can identify specific message words.

The orbital parameters are located in the first 22 words of column 6 and those in lines 9 through 22 are changed only when a new message is injected into the memory. These fixed parameters define a smooth eliptical orbit; satellite position being a function of time since a recent time of orbit perigee.

The words in lines 1 through 8 shift upward one place every two minutes, with a new word inserted each time in line 8. These variable parameters describe the deviation from the smooth ellipse of the actual satellite position at the indicated even minute time marks. Hence, by comparison of the parameters, the satellite's position can be defined at any time during a pass.

## DOPPLER MEASUREMENT

By receiving the navigation message, the navigator learns the position of the satellite as a function of time. However, to obtain a position fix, he must relate his position to the known satellite position.

The previous figure illustrates the Doppler measurement technique. The frequency $f_R$ being received from the satellite consists of the frequency $f_T$ plus a Doppler frequency shift of up to $\pm 8$ kHz due to relative motion between the satellite and receiver. Note that the transmitted frequency is offset low to prevent $f_R$ from crossing 400 MHz.

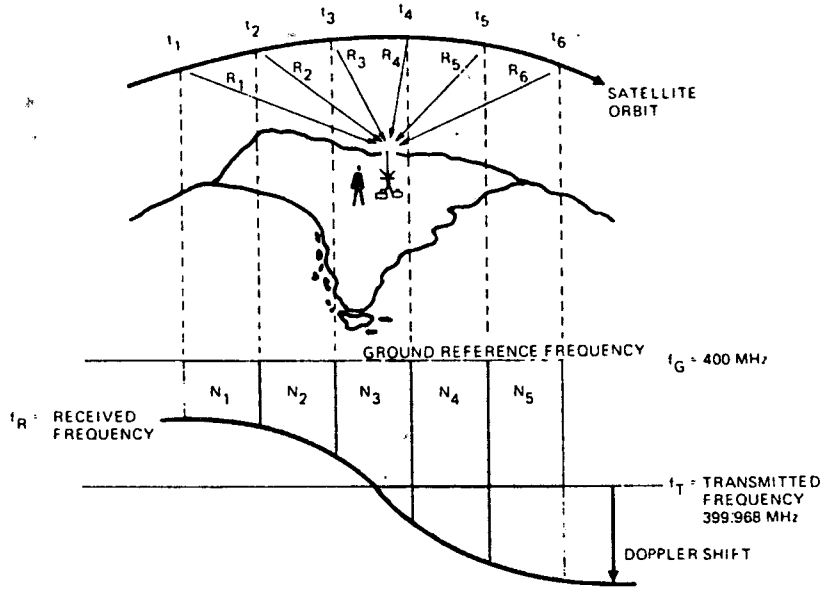



Figure 5 - Each Doppler Count Measures Slant Range Change

The shipborne receiver is equipped with a stable reference oscillator from which a 400 MHz ground reference frequency $f_G$ is derived. As shown by the figure, the receiver forms the difference frequency $f_G - f_R$, and each Doppler measurement is a count of the number of difference frequency cycles occurring between timing marks received from the satellite. Because each message bit effectively represents another time mark, the Doppler counting intervals are formed with respect to the message format. For example, each line of the message lasts about 4.6 seconds, and the commonly used Doppler count interval of 23 seconds is formed by starting a new count at the end of every fifth line.

The figure also illustrates that the distance between the satellite and the observer changes throughout the satellite pass. It is this change which causes the Doppler frequency shift. As the satellite moves closer more cycles per second must be received than were transmitted to account for the shrinking number of wave-lengths along the propagation path. For each wave-length the satellite moves closer, one additional cycle must be received. Therefore the Doppler frequency count is a direct measure of the change in

distance between the receiver and the satellite during the Doppler count interval, ie, the Doppler count is a geometric measure of the difference between the observer and the satellite at two points in space, accurately defined by the navigation message. This is a very sensitive measure as each count represents one wave-length, which at 400 MHz is 0.75 metres.

The Doppler count which measures the slant range is determined in the processor by $f_G - f_R$. Consequently, when the satellite is in the centre of its pass:

$$f_T - f_R = 0$$

$$f_G - f_R = 32 \text{ kHz}$$

20 to 40 Doppler counts are made during each pass and the processor, by decoding the satellite's position, computing slant range and determining ship's velocity, will compute the current position.

## MX1122 RAN - EQUIPMENT DESCRIPTION

The Satellite Navigator is a single channel unit, operating at 400 MHz, consisting of a console which contains the receiver, microprocessor, keyboard and display. The antennae group consists of the antenna and preamplifier combined and the connecting cable. Power to the preamplifier is provided by the connecting cable using the centre conductor and shield.

In the event of a temporary loss of external power, the MX1122 RAN automatically switches to internal battery power, indicates a mains power failure on the display and continues to operate without interruption for approximately 10 minutes. The batteries automatically recharge upon restoration of external power.

### HARDWARE OPTIONS

A printer may be connected to provide a printed record of the navigation display at each fix or at selected time intervals.

An external alarm may be connected that will be activated in:

a. circuit failure;

b. incorrect speed or heading input;

c. mains power failure;

d. the set being switched off;

e. failure to update position by a satellite fix within 10 hours;

f. excessive temperature.

Other options available are remote display, DC operation and the unit can be upgraded to OMEGA operation.

FUNCTIONAL DESCRIPTION

The MX1122 RAN automatically and continuously computes and displays ship's position by monitoring signals from earth-orbiting TRANSIT satellites. After each usable satellite pass, the unit determines and displays the vessel's latitude and longitude within 0.05 nautical miles, then displays the dead reckoning position until the next satellite update.

The unit acquires all satellite information automatically. When two or more satellite signals are available at the same time, the unit tracks the satellite offering the best data.

The MX1122 displays the following information:

a. present dead-reckoned position updated by the satellite fix;

b. Greenwich Mean Time (accurate to 1 second);

c. ship's speed (manual or automatic input);

d. ship's heading (manual or automatic input);

e. Dead Reckoning Time (elapsed time since last update);

f. range and bearing to any point on the earth's surface by Great Circle or Rhumb Line track;

g. set and drift;

h. heading to steer;

i. total distance run;

j. course of advance (course corrected for set and drift and gyro error);

k. speed of advance (speed corrected for set and drift);

l. GMT of next usable satellite pass;

m. GMT of future satellite passes;

n. manual and automatic maintenance displays.

The equipment also has the capability of loading 9 "WAY POINTS" to anywhere in the world and plotting courses by either Rhumb Line or Greater Circle.

POSITIONAL ERROR

There are two principal error components in the system. The

first error component, approximately 0.05 nautical mile, consists of the inherent system error. The second component, approximately 0.2 nautical mile per knot, is introduced by each knot of unknown ship's velocity.

SELF-TEST FACILITY

Every 2 hours and 8 minutes, starting at midnight GMT, the MX1122 performs an automatic self-test of all major functions except the aerial outfit. However, if a satellite is due, this will take precedence over the self-test.

During the self-test, which takes approximately 130 seconds, the word TEST appears on the display and disappears at the end of the test. The test is done in two parts:

FIRST PART

(1) -10V removed from the preamplifier;

(2) an unmodulated signal is injected into the receiver.

DISPLAY - An "A" will appear above "TEST"

- Frequency - 26.6

- Signal strength - low

SECOND PART

a. -10V still removed from the aerial;

b. a modulated signal is injected into the receiver.

DISPLAY - "TEST" will be shown

- frequency counts to 34.8

- signal strength - 100

If an error is found, the notation ERR appears on the display followed by a numeral identifying the most probable defective card or letters identifying the type of failure. The gyro-compass and speed log inputs are also continuously checked. The only unit not checked is the preamplifier.

The self test may be initiated manually by the operator by entering code 16.

MX1122 RAN MAINTENANCE

| | |
|---|---|
| WEEKLY | Check fan operation and ensure good air flow from the exhaust on the front of the console. |
| MONTHLY | Dust the interior of the set with a soft brush. |

4.5 MONTHLY — Rotate console battery with the spare IAW TEM 5825-0014 Vol 2 Chap 2.

9 MONTHLY — Test battery condition. Remove ship's power from the console and operate the set for 10 minutes on the internal battery. If 10 minutes operation cannot be achieved, replace the battery.

REPAIR ACTION

The only onboard repair action required is to change the appropriate card as the only circuits which use discrete components are the power supply and video circuits.

| CODE | DISPLAY | FUNCTION |
|---|---|---|
| 10 | - | Enables auto set and drift |
| 11 | - | Changes display background |
| 12 | - | Recalculate fix |
| 13 | - | Force update |
| 14 | - | Speed auto/manual |
| 15 | - | Heading auto/manual |
| 16 | Test | Self test |
| 17 | Lock | Lock keyboard |
| 20 | Several | Re-initialise |
| 21 | LAT N | Latitude |
| 22 | LON E | Longitude |
| 23 | GMT | GMT |
| 24 | Speed + | Speed |
| 25 | HDG | Heading |
| 26 | ANT H | Antenna Height (metres) |
| 27 | GEO H | Geoidal Height |
| 30 | PLAT I - N | Point latitude ) |
| | PLON I - E | Point longitude ) |
| 34 | FSPD | Synchro scale value |
| 35 | GYRO E = E | Gyro error |
| 36 | SECT R | Gyro ratio |
| 38 | DIST | Distance run |
| 40 | SET | Set (Angle) |
| | DRIFT | Drift (Distance) |
| 43 | L TIME | Local time |
| 44 | L DATE | Local date |
| 45 | LTOFF + | Local time offset |
| 51 | RISE | Satellite predictions |
| 53 | FIX | Last fix |
| 54 | TUNE | Tuned freq/signal strength |
| 56 | REF OS | Reference oscillator offset |
| 57 | MARK | Mark gyro |
| 58 | HDG SET | Heading to steer |
| 60 | - | Great circle |
| 61 | - | Rhumb line |
| 62 | - | Remove range and bearing |
| 64 | SPEED A | Speed of advance |
| 65 | COURSE | Course of advance |

| | | |
|---|---|---|
| 66 | ETA | Estimated time of arrival |
| 70. | - | Point Now |
| 71 | PRINT = | Print Interval |
| 73 | (SEVERAL) | SAT/WAY Point Alerts (9 of) |
| 77 | ROUT | Remote outputs |
| 79 | LINE A | Force programme track |
| 89 | SEVERAL | GMT date |
| 127 | - | Keyboard unlock |
| 255 | LEXPO | Retain satellite info if no pass for 4 days |
| 237 | | Cancel self test. |

INITIALISATION

On entering CODE 20, the MX1122 will step through the initialisation procedure requiring only the relevant information to be entered. If a mistake is made, do not use the "CLEAR" key, use the "BACKSPACE".

The initialisation procedure, including the codes used to change any entry at a later stage, is as follows:

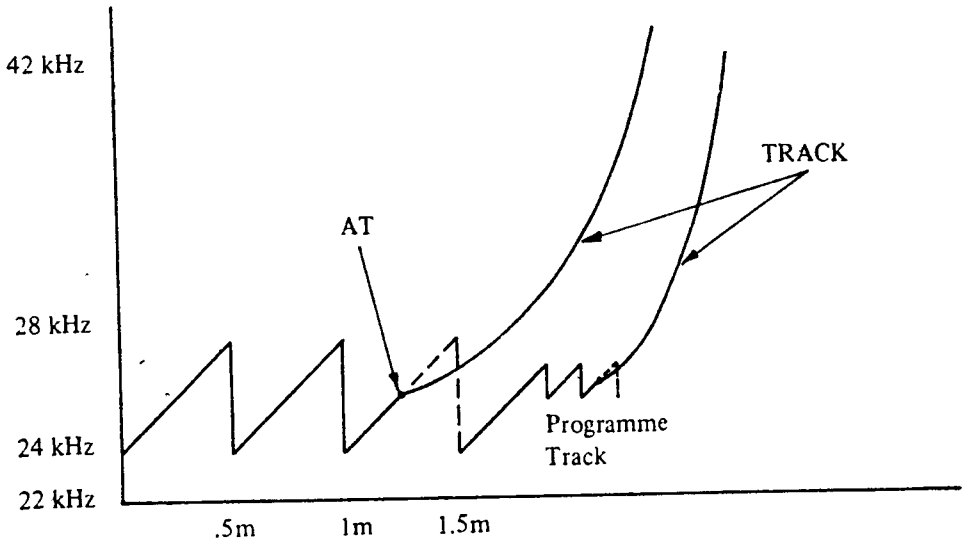
| STEP | CODE | DISPLAY | ACTION |
|---|---|---|---|
| 1 | 77 | R OUT | +/- |
| | | | ENTER |
| 2 | 71 | PRINT | Interval in minutes |
| | | | ENTER |
| 3 | 14 | SPEED M | +/- Speed (manual, auto) |
| | | | ENTER |
| | | HDG M | +/- Heading |
| | | | ENTER |
| 4 | 21 | LAT N | +/- Degrees and 1/10 mins |
| | | | ENTER |
| 5 | 22 | LON E | +/- Degrees and 1/10 mins |
| | | | ENTER |
| 6 | 23 | GMT | Time |
| | | | ENTER |
| 7 | 34 | F SPD | |
| | | | ENTER |
| | | S RAT | |
| | | | ENTER |
| | | SOD E | Speed error offset |
| | | | ENTER |
| 8 | 35 | H RAT | |
| | | | ENTER |
| 9 | 24 | SPD | Speed |
| | | | ENTER |
| 10 | 25 | HDG | Heading |
| | | | ENTER |
| 11 | 26 | ANT H | Antenna Height above sea level |
| | | | ENTER |
| 12 | 27 | GYRO E +E | +/- Gyro error |
| | | | ENTER |
| 13 | 11 | GMT DATE | Date |
| | | | ENTER |

## CONDITIONS OF OPERATION

There are four conditions of operation:

1. SEARCH

During a normal search for data, the frequency slowly sweeps up from 24 to 28 kHz and quickly back down to 24 kHz. This cycle is repeated until satellite data is detected when an "A" appears on line 1 of the display.




2. TRACK

Once the satellite data is acquired the MX1122 will track the frequency change using a phase locked loop system. At this time a "T" will appear beside the A on the display.

3. PROGRAMME TRACK

The set searches around a programmed frequency ± 1 kHz. Normal acquisition time is 5 seonds and an "S" will appear on the display.

4. TEST

The antenna/preamplifier is switched off and the receiver is tested.

## THE MX1122 RAN DISPLAY

The MX1122 RAN shows the standard display whenever the clear C key is pressed. A detailed description of the standard display follows:

LINE 1 The letters S, A, T may be displayed on the left side. S indicates that the MX1122 RAN is searching for a particular satellite, A indicates acquiring a satellite, and T indicates trackig the acquired satellite and collecting data. Dead Reckoning Time (DRT) in hours and minutes, appears at the centre. This is the elapsed time since the last update of the dead-reckoned latitude and longitude position by a satellite fix. The DRT is blank after start-up until the first update occurs. On the right portion of line 1 is the number of consecutive fixes which have not updated the dead reckoned position. This number sequences from N1 to N9. After an update the N area is blank. If an N occurs after every satellite pass, refer to Chapter 6, Maintenance.

LINE 2 Is usually blank. TEST is displayed during self-test and ERR if an error is found. The notation following ERR is for service purposes (see Chapter 6, Maintenance). The right portion displays active alerts.

LINE 3 Displays the ship's present latitude in degrees, minutes and hundredths (1/100) of minutes.

LINE 4 Displays the present longitude in degrees, minutes and hundredths (1/100) of minutes.

LINE 5 Displays the present Greenwich Mean Time (GMT) in hours, minutes and seconds. GMT is correct to within 1 second.

LINE 6 Is blank unless the range and bearing to a selected way point have been requested by the navigator. Refer to codes 30, 60, 61 and 62 for details.

LINE 7 Displays the speed and heading which is input for dead-reckoning. Speed is in knots and heading is in degrees. The letter M to the left of speed or heading indicated that the respective input is manually entered. The displayed heading is the gyro compass heading corrected by the gyro compass error (code 35).

LINE 8 Displays the present set and drift correction being applied to the dead reckoning. See codes 40 and 10 for details.

LINE 9 The word LOCK appears on the left side when the keyboard is locked out by code 17. LOCK can be removed by entering code 127. The centre portion of line 9 is used to display values requested by the navigator. The word MAGNAVOX is displayed on the right side.

LINE 10 Displays code words and numbers entered through the keyboard. Line 10 can be cleared of this data by pressing the clear C key. The word POWER appears on the right side when primary power has been interrupted.

MX1122 RAN BUS

The set incorporates 3 major bus system:

a. ADDRESS

b. DATA

c. PROTOCOL

ADDRESS BUS

This bus directs cards to accept information. The address information is generated in CARD 4 and directed to CARDS 1, 2 and 3.

DATA BUS

The DATA BUS is divided into 2 sections, INPUT and OUTPUT.

The INPUT BUS conveys satellite data, doppler counts, speed and heading data and keyboard data to CARDS 3 and 4 in 8 bit format, on lines IB0 → 1B7.

The OUTPUT BUS conveys data from CARD 4 to CARDS 2 and 7 in 8 bit format on lines OB0 → OB7.

PROTOCOL BUS

The PROTOCOL BUS which conveys orders with regard to the priority order of information, is sub-divided into 3 sub bus:

a. SELECT BUS. The information is in 6 bit format and selects the appropriate address using SELECT 0 → SELECT 5 which form the decoded address.

b. FLAG BUS. The information is in 8 bit format and consists of orders FLAG 0 → FLAG 7 and acknowledgements FLAK 0 → FLAK 7.

c. INTERRUPT BUS. There is the capability of 7 intrrupts INT 1 → INT 7 and 7 acknowledgements INAK 1 → INAK 7. This information is in 7 bit format, however, there is only 1 used and it takes priority.

ANTENNA/PREAMPLIFIER

The mono-polar antenna and preamplifier are combined in one unit to provide a good signal-to-noise ratio:

| | |
|---|---|
| GAIN | 24dB |
| BW | 4 MHz at -6dB |
| CURRENT DRAW | 25-35 mA |
| VOLTAGE | -10VDC |
| CABLE LOSS | 5dB/30m |

CARD 1 SPEED AND HEADING

It converts speed and synchro information into machine language, can handle 2 synchro speed inputs (36:1, 1:1), however, for the MX1122 a

junction box is required.

SPEED/HEADING JUNCTION BOX (PSC)

This unit converts contact closure to synchro information.

| | | |
|---|---|---|
| I/P POWER | VOLTAGE | 98-132 VAC |
| | FREQUENCY | 60Hz + 10% |
| | CURRENT | 0.25A |
| SYNCHRO | VOLTAGE | 48-144 VAC |
| | FREQUENCY | 47-63Hz |
| LOGIC | LL "1" | +2.5VDC |
| | LL "0" | 0.7VDC |
| CONTACTS | Min Closure Time | 10m sec |
| | Min Open Time | 10m sec |
| | Max Repetition Rate | 5 close/sec → 359° |
| | Max Repetition Rate | 0.8 close/sec → 0° |

Pin connections on Terminal Board:

| | | |
|---|---|---|
| 1 | $R_1$ | ) |
| 2 | $R_2$ | ) |
| 3 | $S_1$ | ) 1122 |
| 4 | $S_2$ | ) |
| 5 | $S_3$ | ) |
| 6 | INPUT + | ) SPEED LOG |
| 7 | INPUT - | ) |
| 8 | NC | |
| 9 | NC | |
| 10) | | ) |
| 11) | 110 VAC | ) POWER |
| 12 | GROUND | ) |

CARD 2 KEY/DISPLAY

This card provides the interface between the console keyboard, display unit, remote displays, printer and processor. It also incorporates the 5VDC power supply.

DISPLAY

When a key is depressed< it puts an "0" into the keyboard encoder, and sends a FLAG 7 to DATA SELECT which becomes a FLAG 7 that goes to the processor. This FLAG 7 comes back on pin 74 to the KEYBOARD ENCODER which enables it allowing an 8 bit word to pass through the enabled DATA BUFFER to the processor.

The keyboard information from the processor, on PINS 23-30 and 95, is clocked through the DATA BUFFER to RAM and addressed to the CHARACTER GENERATOR and subsequently to the display.

The printed information from the processor, on PINS 23-30 and 95, goes to the PRINTER INTERFACE and is passed via PIN 68 to an external printer.

CARD 3 MEMORY

The memory card has 36 K of ROM and is expandable to 65K.

All the chips on CARD 3 have the same address but only one at a time has power applied to it.

The CARD 3 RAM is utilized as an overflow for the processor RAM, eg for speed and heading.

MOTHER BOARD

It provides interconnection between all the cards.

The equipment cards are not positionally keyed but they may be fitted in any position without damage as the power connection pins are common, however if they are incorrectly positioned, the set will not operate.

CARD 4 PROCESSOR

This card interfaces with all the cards except the satellite receiver card. It contains the computer in the form of an 8080 microprocessor, an 8 bit x 2K RAM, a 2MHz oscillator and the logic necessary to handle interrupts, addresses and address codes, memory commands and the input and output data.

The processor timing is supplied by the 2MHz oscillator. Interrupt timing is controlled by the 100kHz from CARD 8 which is derived from the 5MHz reference oscillator. The processor samples speed and heading at 10m sec intervals.

An interrupt from the SATELLITE INTERFACE CARD tells the processor that satellite information is ready. The processor responds with demands for data. The satellite data is stored in the RAM, and the processor conducts the calculations necessary to produce the navigation information.

CARD 7 SATELLITE INTERFACE

This card contains the logic necessary to communicate with the processor and accept the digitised data from the SATELLITE RECEIVER. It also relays information from the processor to the receiver regarding satellite tracking requirements.

When satellite data is detected by this card, an interrupt is sent to the processor which responds with four demands. The data is sent to the DATA IN BUS in four consecutive 8 bit bytes. CARD 7 has its own self-test generator which is controlled by the processor.

FUNCTIONS

a. Convert raw satellite data from the 8 CARD to machine language;

b. Develop self-test signals and VCO control signals.

CARD 8 SATELLITE RECEIVER

CARD 8 has 3 functions:

a. To extract the DOPPLER signal and Q and I signals from the RF signal. The Q signal carries the satellite data and the I signal is the same signal rotated by 90° which gives the phase error and signal strength.

b. Provide:

(1) 1.67MHz for timing CARD 7;

(2) 375 and 25 MHz for demodulating the satellite signal. These frequencies are developed by multiplying the 5MHz REFERENCE OSCILLATOR frequency;

(3) 400MHz for the SELF TEST. This signal is derived from CARD 7 and multiplied in CARD 8.

c. Develop -10VDC for the antenna/preamplifier.

The transmitted satellite frequency, at 399.968MHz ± 10kHz, is received, amplified and mixed to provide an intermediate frequency of 32kHz ±10kHz which is the raw doppler signal.

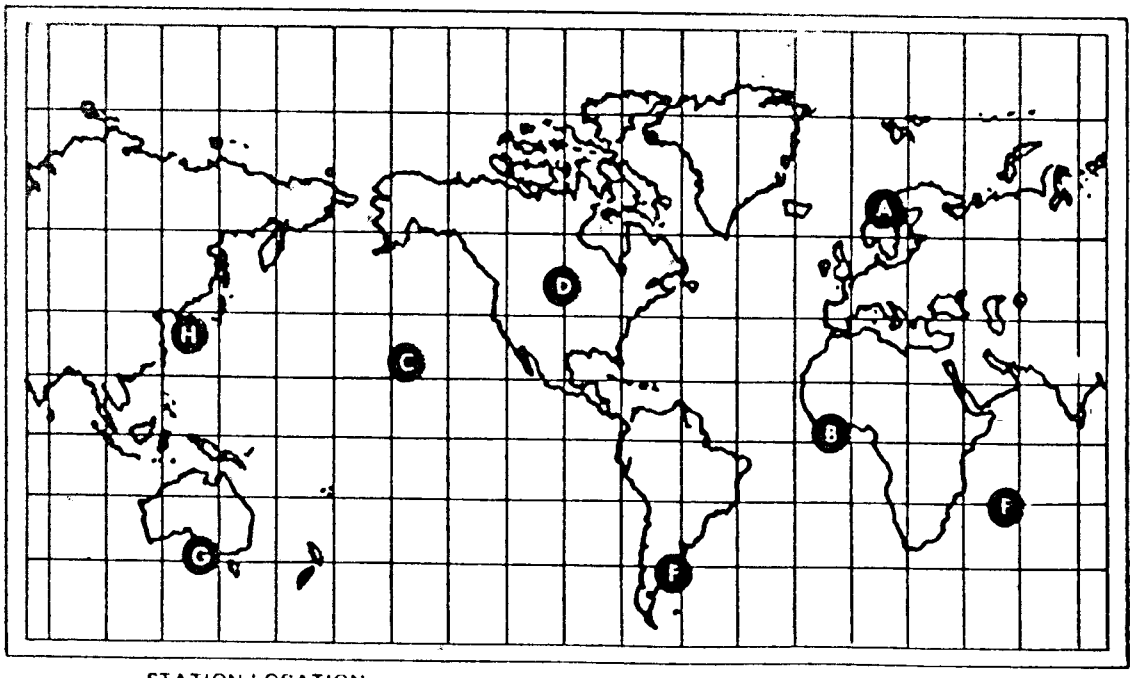
The resultant varying frequency is sampled by a digital encoder to produce the doppler signal in digital form. The encoder also accepts inputs from the SATELLITE INTERFACE which enables it to maintain an acceptable track and phase relationship on the incoming doppler.

| | |
|---|---|
| SATELLITE FREQUENCY AT CENTRE OF PASS | 399.968mHz ± DOPPLER |
| MIXER INJECTION FREQUENCY | 375mHz |
| IF AMPLIFIER OUTPUT | 32kHz ± 10kHz DOPPLER |
| DOPPLER SPREAD | 22 + 42 kHz |

The satellite signal also contains a phase modulated navigation message which is demodulated by using a phase locked loop. This information is used in the processor to correct the navigation message.

# OMEGA SYSTEM

Omega is a world wide radio navigation system operating in the VLF portion of the radio spectrum (3 Khz to 30 Khz).
Due to the low attenuation at these frequences,
( 10.2, 11.3, 13.6 Khz), the reliable service area for each transmitter extends over 10000 nM.
Eight permanent Omega stations are in operation:

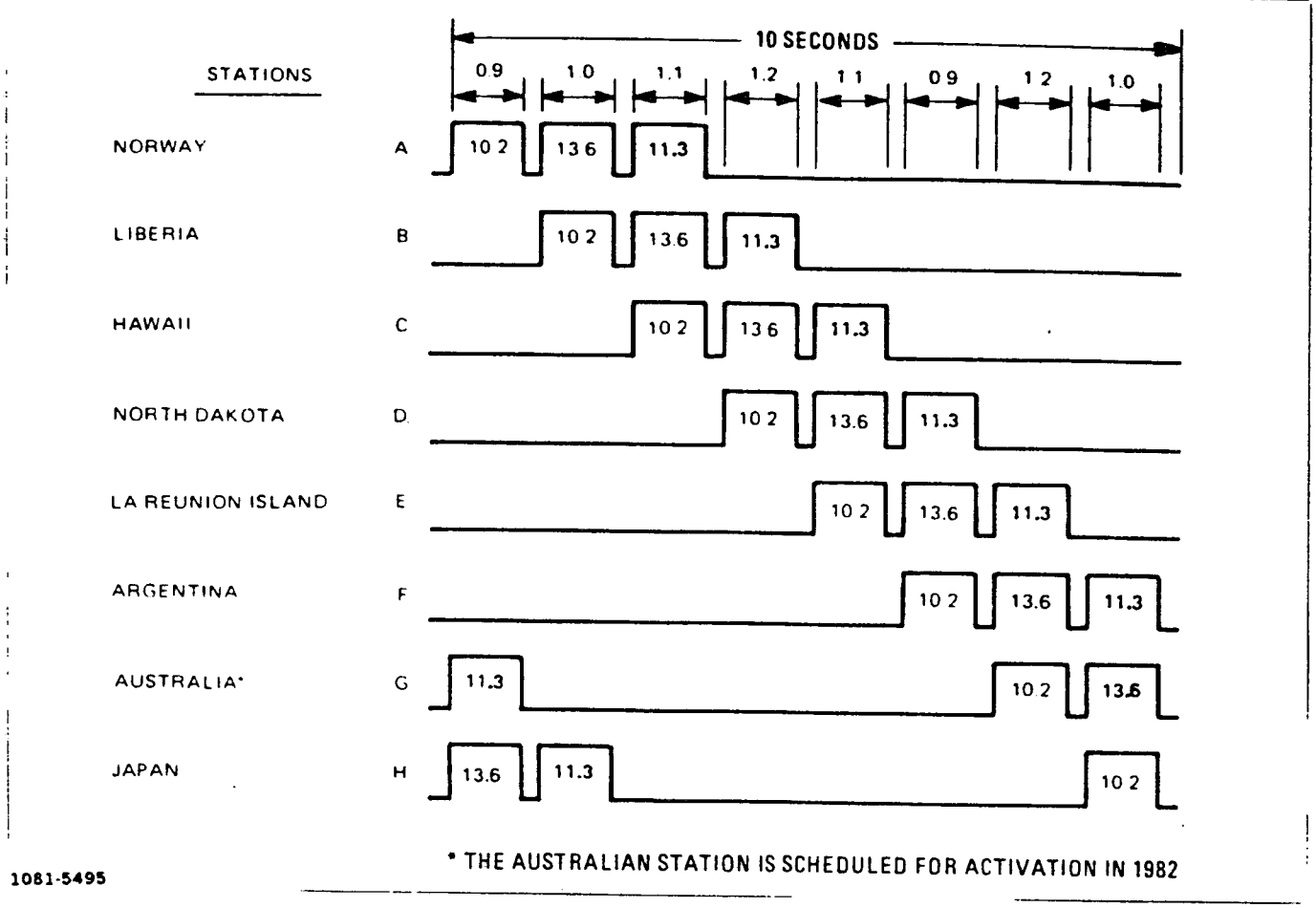



| STATION LOCATION | STATION LOCATION |
|---|---|
| A ALDRA NORWAY | E LA REUNION ISLAND |
| B LIBERIA | F TRELEW, ARGENTINA |
| C HAIKU, HAWAII | G AUSTRALIA * |
| D LA MOURE, NORTH DAKOTA | H TSUSHIMA, JAPAN |

* THE AUSTRALIAN STATION IS SCHEDULED FOR ACTIVATION IN 1982

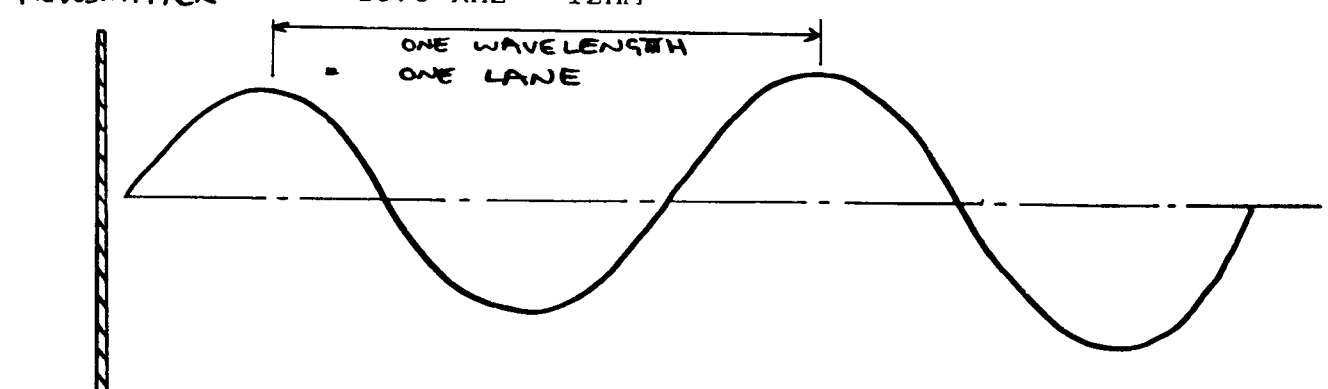
1081-5494

Each transmits three frequencies (10.2,11.3,13.6Khz) time sequenced within a basic pattern 10 seconds in length.




The transmitted signals radiate out in a circular pattern from the station. Each of the three frequencies creates a series of concentric circles (called LANES) around the Omega transmitter. At one of these circles the phase of the Omega signal is the same as the phase of the signal at the transmitter. The distance between the circles is proportional to the wavelength.

10.2 kHz = 16nM
11.3 kHz = 14nM
13.6 kHz = 12nM



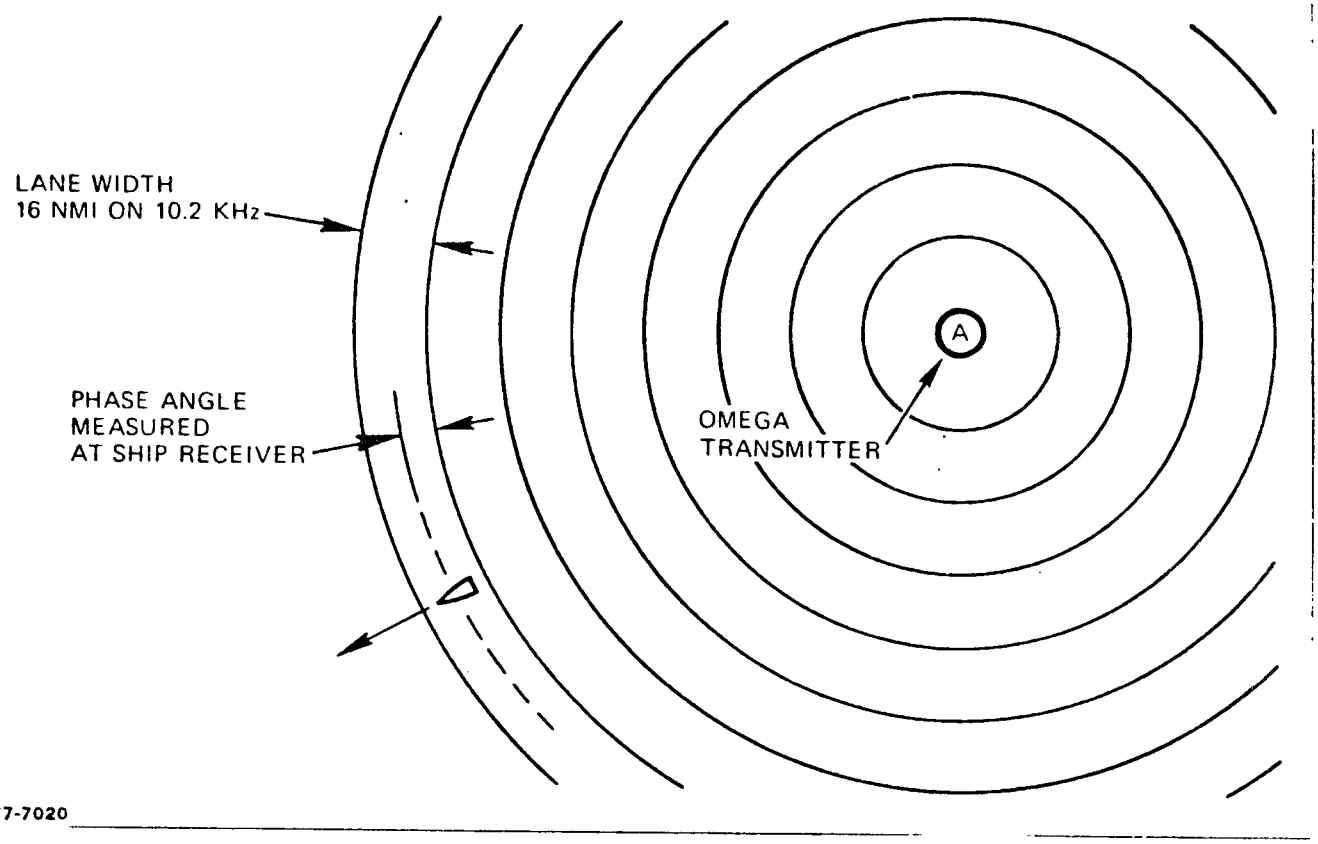



Figure 1-8. Omega Lane Pattern

As the Omega reciever travels within one of these LANES, the PHASE of the recieved Omega signal will gradually change and can be used to measure the movement of the reciever. By utilizing the Omega signal phase information from at least three Omega Stations, the SAT/NAV can calculate the VELOCITY and DIRECTION of travel, of the Submarine.
The Omega reciever must be told where it is initially. This is because the reciever actually counts the number of LANES it has crossed to give the required data.
Occasionally, because of signal strength, the reciever may be unable to track the correct LANE COUNT, resulting in large navigational errors. This is called LANE SLIP. Lane slip is corrected at the next SATELLITE fix.

ERRORS can occur because of the following reasons:
(1) To close to the transmitter.
(2) Ionospheric height due to TIME of day/night.
(3) Unpredictable solar activity.
Although compensation (PROPAGATION CORRECTION ) is provided these effects can combine to produce large errors and this mode is not trusted by the navigators.

# SUBIRS MK 3NRS

GENERAL:
The MK 3NRS system carried onboard R.A.N. Submarines is powered by 115V 60 Hz 3 Phase.
The main components of SUBIRS are :

(A) One Amplifier assembly comprising:
  (1) One Cubical.
  (2) Two Power Units.
  (3) Two Ratemeter and Alarm Units.
  (4) One Test Unit.
(B) One Detecting Unit (WATER).
(C) One Detecting Unit (AIR).
(D) One Indication Unit.

The cubical itself houses the Power Units, Ratemeter and Alarm Units and the Test Unit.

POWER UNITS:
All controls are on the front panel.
This unit meets all power requirements except the Audio Alarms, which are :

(A) 12V DC Negative Stabilised, 90 mA
(B) 12V DC Positive Stabilised, 50 mA
(C) 18V DC Negative Stabilised, 1 mA
(D) 320-425V DC Stabilised [for GM tubes], 7.5 mA
(E) 24V DC Negative Stabilised, 200 mA
(F) 24V AC Unstabilised, 360 mA

The Power Unit will operate on 115V 60Hz with a total power consumption of 60 W.

RATEMETER AND ALARM UNITS:
All controls are mounted on the front panel and these controls provide for Air and Water channel calibration, setting and resetting of the Alarm System, and functional testing of the Ratemeter System.
The Ratemeters are electrically identical and are interchangeable between Air dose rate and water activity channels. As the Sensitivity required of the water activity differs from that of the Air Dose rate channel, arrangements have been made which render recalibration un-necessary when the ratemeters are interchanged.
Certain components in the ratemeter circuit are duplicated and these are connected to a diode pump circuit by connections in the Cubical wiring external to the units. If the two units are in turn plugged into the water activity channel and calibrated for this, then, in turn, plugged into the Air Dose rate channel and again calibrated, the calibration will hold good when interchanged. Alarm operating circuits are included in this unit.

TEST UNIT:
On the front of this unit is a Meter, a Magnetic Alarm indicator and a function switch. All other components are mounted to a bracket screwed to the Back of the front panel. This unit provides facilities for setting up all the Power Unit Supply Lines and the Alarm levels.

DETECTING UNITS:
AIR-
This unit is housed in a sealed case and contains the GM tube and a Head Amplifier. It is situated in the Snort Head.
WATER-
Electrically, this unit is identical to the AIR detector but mechanically, they differ considerably. The sealed inner case is fabricated from Mild Steel and houses the electrical components. The only differance here between the two units is that the GM tube in the WATER detector is partially shielded by LEAD to minimise detection of any Air activity

DETECTING UNITS: WATER-Cont.
inside the Submarine or surface activity above it. The outer case is also fabricated from Mild Steel. The WATER detector is mounted in the Submarine below the water line (usually in the Engineers Store).

INDICATING UNIT:
All components are situated on the hinged front panel, which incorporates low level PLASTECK illumination. Continuous indication of the Air dose rate and Water activity is provided on two moving coil meters. Under normal conditions the Magnetic visual indicator will show the word "ON". If the alarm level is exceeded, they will show "HIGH", and if the power fails they will show a black and white hatching.
A switch on the indicating panel MUTES the audible Alarm. Once the MUTE switch has been operated, the Alarm will stay silent until the RESET switch ( also on the front panel ) has been operated. If the RESET switch is operated while the activity is above the alarm level, the alarm will sound again. To reset the alarm circuit, it is necessary to operate the RESET switch, since the circuit does not reset itself when activity falls below the Trigger Level.